



Description of the degree program

# Electrical Engineering and Information Technology (Master) PO 5

Date: 05.10.2026

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### Master Electrical Engineering and Information Technology

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**Compulsory Module**

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Ambits of Electromagnetic Field Theory       |                   |                                                               |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2419110                                      | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              | Language          | english german                                                |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                                            | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 4 / 5,0                                      | Module owner      |                                                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                                          |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 56                                           | Self studying (h) | 94                                                            |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Written exam (120 min) or oral exam (30 min) |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                               |
| <ul style="list-style-type: none"><li>• Energetic considerations, Poynting theorem, equivalent circuit</li><li>• Potentials in the dynamic case, Hertzian dipole and radiation, approximations for the field descriptions</li><li>• Analytical calculation methods and examples, numerical field calculation</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                               |
| The students can explain the structure of the Maxwell equations in differential form, herefrom derive the fully dynamic field solution of the Hertzian dipole and, depending on the special case, give reasons for idealized approximate solutions. By this they can analyze fundamental electrotechnical configurations and abstract to the essential details. They can choose and apply appropriate solution methods for example for energetic problems, Poynting theorem and temporal and spatial variable fields. They can integrate electromagnetic interactions into the Schrödinger equation of quantum mechanics and solve elementary problems in this context. They are familiar with applications of field theory in the field of antenna design. |                                              |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                               |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                               |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                               |
| Students can either choose this module or the module "Advanced Applications of Field Theory". It is not possible to attend both.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                               |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 2,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Advanced Applications of Field Theory        |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2420000080                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                            | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4 / 5,0                                      | Module owner      | Prof. Dr. Thomas Kämpfe                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>• Potential formalism: scalar potential and vector potential</li><li>• Energy considerations, Poynting theorem</li><li>• Potentials for the dynamic case, Hertzian dipole and radiation, approximations in field descriptions</li><li>• Field theory in quantum mechanics: electromagnetic interactions in Schrödinger theory</li><li>• Field theory in microelectronics: Propagators and Green's function, effective and field theory for antenna design</li></ul>                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| Upon completion of the module, students will be able to explain the structure of Maxwell's equations in differential form, derive the fully dynamic field solution of Hertz's dipole from this, and justify idealized approximate solutions depending on the application. This will enable them to analyze basic electrical engineering arrangements using field theory methods and abstract the essential details. They can select and apply suitable solution methods, for example, for energy problems, Poynting's theorem, and fields that vary in time and space. They can integrate electromagnetic interactions into the Schrödinger equation of quantum mechanics and solve elementary problems in this context. They are familiar with applications of field theory in the field of antenna design. |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| D.J. Griffiths: Electrodynamics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |                   |                                                          |
| J.D. Jackson: Classical Electrodynamics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| A.Enders: Electromagnetic Fields (TU Braunschweig)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                              |                   |                                                          |
| Students can either choose this module or the module "Ambits of Electromagetic Field Theory". It is not possible to attend both.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |



|                                                    |            |                  |                 |
|----------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                             |            |                  |                 |
| <b>Rules for the choice of courses</b>             |            |                  |                 |
|                                                    |            |                  |                 |
| <b>Compulsory attendance</b>                       |            |                  |                 |
|                                                    |            |                  |                 |
| <b>Name of the course</b>                          | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Advanced Applications of Field Theory              | 2,0        | Lecture          | english         |
| <b>Literature</b>                                  |            |                  |                 |
| D.J. Griffiths: Electrodynamics                    |            |                  |                 |
| J.D. Jackson: Classical Electrodynamics            |            |                  |                 |
| A.Enders: Electromagnetic Fields (TU Braunschweig) |            |                  |                 |
| Advanced Applications of Field Theory              | 2,0        | Exercise         | english         |
| <b>Literature</b>                                  |            |                  |                 |
| D.J. Griffiths: Electrodynamics                    |            |                  |                 |
| J.D. Jackson: Classical Electrodynamics            |            |                  |                 |
| A.Enders: Electromagnetic Fields (TU Braunschweig) |            |                  |                 |

**Major Specialisation: Information Technologies - Compulsory Elective Modules**

|                                                                                                                                                                                                                                                                                                                                                 |                                              |                   |                                                          |
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| Title                                                                                                                                                                                                                                                                                                                                           | Coding Theory                                |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                          | 2424420                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                       |                                              | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                              | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                 | 1                                            | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                           | 4 / 5,0                                      | Module owner      | Prof. Dr. Thomas Kürner                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                    | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                            | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                         |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                       | Oral exam (20 min) or written exam (120 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                              | Colloquium or lab journal                    |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                        |                                              |                   |                                                          |
| <div>- Introduction</div> <div>- Fundamentals of information theory</div> <div>- Basics of channel coding</div> <div>- Single-error-correcting block codes</div> <div>- Block codes for correcting burst errors</div> <div>- Convolutional codes</div> <div>- Special coding techniques</div>                                                   |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                         |                                              |                   |                                                          |
| Upon completion of the module, students will have an understanding of the information-theoretical limits of data transmission and will have acquired knowledge of source and channel coding methods in theory and application. Students will be able to assess the performance of source and channel coding methods and construct simple codes. |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| Lecture notes<br>H.Rohling: Einführung in die Informations- und Codierungstheorie, Teubner<br>R.Togneri, C.J.S. deSilva: Fundamentals of Information Theory and Coding Design, Chapman&Hall/CRC<br>H.Schneider-Obermann: Kanalcodierung, Vieweg                                                                                                 |                                              |                   |                                                          |





|                                                                                                                                                                                                                                                          |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Coding Theory                                                                                                                                                                                                                                            | 2,0        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                        |            |                  |                 |
| Vorlesungsskript<br>H. Rohling: Einführung in die Informations- und Codierungstheorie, Teubner<br>R. Togneri, C. J. S. de Silva: Fundamentals of Information Theory and Coding Design, Chapman&Hall/CRC<br>H. Schneider-Obermann: Kanalcodierung, Vieweg |            |                  |                 |
| Coding Theory                                                                                                                                                                                                                                            | 1,0        | Exercise         | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                        |            |                  |                 |
| siehe Vorlesung                                                                                                                                                                                                                                          |            |                  |                 |
| Computer exercise on Coding Theory                                                                                                                                                                                                                       | 1,0        | Laboratory       | english german  |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                            |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Electromagnetic Theory for Microwave Engineering                                                                           |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2415490                                                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                            | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | only in the winter term                                                                                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                                                                                                          | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 4 / 6,0                                                                                                                    | Module owner      | Prof. Dr. Jörg Schöbel                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 180                                                                                                                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 56                                                                                                                         | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                            |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | written examination 90 minutes or oral examination 30 minutes or homework assignments or semester project assignment (§ 4) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                            |                   |                                                          |
| <div>- Theory of time-harmonic electromagnetic fields (Maxwell's equations, wave equation, Poynting's theorem, uniqueness theorem, reciprocity)</div> <div>- Methods of calculation (vector potentials, Lorenz gauge, solution of the (in)homogeneous wave equation, source integrals, Green's function)</div> <div>- Eigenmodes of waveguides, surface waves, leaky waves</div> <div>- Radiation fields (Huygens' principle, image theory, Fresnel and Fraunhofer approximations)</div> <div>- Introduction to the numerical solution of electromagnetic problems (FDTD, method of moments, eigenmode expansion)</div> <div>- Exemplary implementation of solution methods in Matlab or Python</div> <div>- simulation of electromagnetic structures using commercial 3D-EM-software</div>                                                                                                                                                                                                                                                                                       |                                                                                                                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                            |                   |                                                          |
| <div>After completing the module, students will have in-depth knowledge and a well-founded conceptual understanding of the theory of electromagnetic waves with respect to the solution of the homogeneous wave equation (waveguide structures) as well as of the inhomogeneous wave equation (antennas). They have become familiar with different analytical and numerical solution methods for electromagnetic problems and exemplarily implemented selected methods as well as applied them in the context of commercial 3D-EM software. They will be able to select problem-adapted solution methods and to apply them competently to electromagnetic problems.</div> <div>According to the didactic concept of the course and the design of its individual parts, interdisciplinary qualifications are conveyed and practiced. In the context of assignments, colloquia and presentations these are scientific writing and documentation, scientific discussions and presentation techniques as well as teamwork in the laboratory or within team project assignments.</div> |                                                                                                                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                            |                   |                                                          |
| <div>Harrington, Time-harmonic Electromagnetic Fields, Wiley &amp; Sons, ISBN 047120806X</div> <div>Unger, Elektromagnetische Theorie für die Hochfrequenztechnik I + II, Hüthig, ISBN 377851573X, ISBN 3778515748</div> <div>Pozar, Microwave Engineering, Wiley &amp; Sons, ASIN B001QA4I9C</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                            |                   |                                                          |



|                                        |            |                    |                 |
|----------------------------------------|------------|--------------------|-----------------|
| <b>Related courses</b>                 |            |                    |                 |
| <b>Rules for the choice of courses</b> |            |                    |                 |
|                                        |            |                    |                 |
| <b>Compulsory attendance</b>           |            |                    |                 |
|                                        |            |                    |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b>   | <b>Language</b> |
|                                        | 2,0        | Lecture            | german          |
|                                        | 1,0        | Exercise           | german          |
|                                        | 1,0        | Practical exercise | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Information Theory                          |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2424720                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                           | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3 / 5,0                                     | Module owner      | Prof. Dr. Eduard Jorswieck                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>Basics from probability theory<ul style="list-style-type: none"><li>Event, probability, random variable, random vector, stochastic process, convergence of random series, convergence theorems</li></ul></li><li>Basics from information theory<ul style="list-style-type: none"><li>Measures for discrete random variables: entropy, conditional entropy, relativ entropy, mutual information, conditional mutual information, inequalities</li><li>Measures for continous random variables: differential entropy, conditional differential entropy, relative entropy, mutual information, inequalities</li><li>Measure for random series</li><li>Typical sequences and asymptotic equipartition property</li></ul></li><li>Source and source coding<ul style="list-style-type: none"><li>Definition and properties</li><li>Source coding for discrete memoryless sources (fixed and variable-length)</li><li>Selected source codes: Morse, Huffman, Shannon-Fano-Elias</li></ul></li><li>Data transmission and channel capacity<ul style="list-style-type: none"><li>Discrete memoryless channel: channel coding theorem</li><li>Discrete memoryless channel with state: channel capacities</li><li>Gaussian channel: model and channel coding theorem</li><li>Bandlimited Gaussian channel, vector valued channels</li></ul></li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| The lecture provides an introduction to the fundamentals of Shannon information theory. The goal is that students can derive the main information theoretic results on maximal achievable lossless (source coding) and lossy (rate distortion theory) compression of data and on maximum data rates for reliable data transmission (channel coding). The methods and tools required, e.g., information measures (entropy, mutual information, capacity etc.) and their properties (typical sequences) will be covered as well as practical applicable simple codes (block, turbo and polar codes).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| #R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.<br>R.W. Yeung: A First Course in Information Theory. Springer. 2002.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |

T.M. Cover und J.A. Thomas: Elements of Information Theory, Wiley-Interscience, 2006.  
 R.G. Gallager: Information Theory and Reliable Communication, Wiley, 1968.  
 R.G. Gallager: Principles of Digital Communication, Cambridge University Press, 2008.  
 S. Moser: S. Moser: Information Theory, <https://moser-isi.ethz.ch/scripts.html#it>



| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |     |           |          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----------|----------|
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |     |           |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |           |          |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |     |           |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |           |          |
| Name of the course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | SWS | Eventtype | Language |
| Information Theory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2,0 | Lecture   | english  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     |           |          |
| <ul style="list-style-type: none"> <li>- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008</li> <li>- R.W. Yeung: A First Course in Information Theory, Springer, 2002</li> <li>- T.M. Cover und J.A. Thomas: Elements of Information Theory, Wiley-Interscience, 2006</li> <li>- R.G. Gallager: Information Theory and Reliable Communication, Wiley, 1968</li> <li>- R.G. Gallager: Principles of Digital Communication, Cambridge University Press, 2008</li> <li>- S. Moser: S. Moser: Information Theory, <a href="https://moser-isi.ethz.ch/scripts.html#it">https://moser-isi.ethz.ch/scripts.html#it</a></li> </ul> |     |           |          |
| Information Theory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1,0 | Exercise  | english  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     |           |          |
| <ul style="list-style-type: none"> <li>- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008</li> <li>- R.W. Yeung: A First Course in Information Theory, Springer, 2002</li> <li>- T.M. Cover und J.A. Thomas: Elements of Information Theory, Wiley-Interscience, 2006</li> <li>- R.G. Gallager: Information Theory and Reliable Communication, Wiley, 1968</li> <li>- R.G. Gallager: Principles of Digital Communication, Cambridge University Press, 2008</li> <li>- S. Moser: S. Moser: Information Theory, <a href="https://moser-isi.ethz.ch/scripts.html#it">https://moser-isi.ethz.ch/scripts.html#it</a></li> </ul> |     |           |          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | New Architecture and Protocols in Communication Networks |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2416760                                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                          | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | only in the summer term                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1                                                        | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 3 / 5,0                                                  | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 150                                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 42                                                       | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                          |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Written exam (90 min) or oral exam (30 min)              |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                          |                   |                                                          |
| <ul style="list-style-type: none"><li>• Introduction to broadband communication</li><li>• Broadband access networks</li><li>• Optical Networks</li><li>• Control and management of broadband networks</li><li>• Wireless broadband networks</li><li>• Applications of broadband networks</li></ul>                                                                                                                                                                                                     |                                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                          |                   |                                                          |
| After completing this module, students will have in-depth knowledge of architectures and signaling protocols of new architecture and protocols in advanced communication networks, including the access networks, core and backone networks, optical transport networks, wireless networks and virtual private networks, such as data center networks and campus networks. The fundamentals learned enable students to design, analyze and evaluate new protocols, services and network architectures. |                                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                          |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                          |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|                                                                    |     |          |                |
|--------------------------------------------------------------------|-----|----------|----------------|
|                                                                    | 2,0 | Lecture  | german         |
| <b>Literature</b>                                                  |     |          |                |
| Include latest research papers, tutorials and industrial standards |     |          |                |
|                                                                    | 1,0 | Exercise | english german |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Optimization and AI for Communication Networks |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2424000060                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the summer term                        | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                              | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                        | Module owner      | Prof. Dr. Eduard Jorswieck                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                            |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 42                                             | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Written exam (60 min) or oral exam (30 min)    |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                |                   |                                                          |
| <ul style="list-style-type: none"><li>• General introduction and fundamentals of machine learning</li><li>• Introduction to learning and machine learning: supervised/unsupervised/reinforcement learning</li><li>• Revision of probability and statistics</li><li>• Revision of linear algebra</li><li>• Fundamentals of numerical optimization</li><li>• Introduction to machine learning assisted linear regression and classification</li><li>• Machine learning for wireless communications</li><li>• Machine learning for physical layer design</li><li>• Advanced AI methods: LLMs and optimization</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                           |                                                |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                |                   |                                                          |
| <p>Artificial intelligence and machine learning have entered all areas of modern engineering. In this module, students will learn the fundamental mechanisms and concepts behind AI and machine learning in the context of communication engineering and apply them to current developments in 6G and WiFi.</p> <p>Students will:</p> <ul style="list-style-type: none"><li>• be familiar with the mathematical foundations of numerical optimization</li><li>• understand deterministic and stochastic gradient descent algorithms, which are used in nearly all ML algorithms</li><li>• be able to formulate regression problems and solve them using Python programs</li><li>• be able to formulate classification problems and solve them using supervised and unsupervised learning algorithms in Python</li><li>• apply advanced ML and LLM methods to optimize the physical layer in modern communication systems</li><li>• independently carry out small projects on the optimization of network parameters.</li></ul> |                                                |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                |                   |                                                          |
| [1] Y. C. Eldar, A. Goldsmith, D. Gündüz, H. V. Poor, Machine Learning and Wireless Communications, Cambridge University Press, 2022.[2] Watt, Jeremy, Reza Borhani, and Aggelos K. Katsaggelos. Machine learning refined: Foundations, algorithms, and applications. Cambridge University Press, 2020.[3] Deisenroth, Marc Peter, A. Aldo Faisal, and Cheng Soon Ong. Mathematics for machine learning. Cambridge University Press, 2020.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                |                   |                                                          |





|                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Optimization and AI for Communication Networks                                                                                                                                                                                                                                                                                                                                                                                                                    | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <p>[1] Y. C. Eldar, A. Goldsmith, D. Gündüz, H. V. Poor, Machine Learning and Wireless Communications, Cambridge University Press, 2022.</p> <p>[2] Watt, Jeremy, Reza Borhani, and Aggelos K. Katsaggelos. Machine learning refined: Foundations, algorithms, and applications. Cambridge University Press, 2020.</p> <p>[3] Deisenroth, Marc Peter, A. Aldo Faisal, and Cheng Soon Ong. Mathematics for machine learning. Cambridge University Press, 2020.</p> |            |                  |                 |
| Optimization and AI for Communication Networks                                                                                                                                                                                                                                                                                                                                                                                                                    | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <p>[1] Y. C. Eldar, A. Goldsmith, D. Gündüz, H. V. Poor, Machine Learning and Wireless Communications, Cambridge University Press, 2022.</p> <p>[2] Watt, Jeremy, Reza Borhani, and Aggelos K. Katsaggelos. Machine learning refined: Foundations, algorithms, and applications. Cambridge University Press, 2020.</p> <p>[3] Deisenroth, Marc Peter, A. Aldo Faisal, and Cheng Soon Ong. Mathematics for machine learning. Cambridge University Press, 2020.</p> |            |                  |                 |

**Major Specialisation: Information Technologies - Elective Modules**

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Quality Assurance and Optimization                                                          |                   |                                                                        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2411220                                                                                     | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                             | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | only in the winter term                                                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1                                                                                           | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 4 / 5,0                                                                                     | Module owner      | Prof. Dr. Oleksandr Dobrovolskiy                                       |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 150                                                                                         |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 56                                                                                          | Self studying (h) | 94                                                                     |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                             |                   |                                                                        |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Written exam (45 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                             |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                             |                   |                                                                        |
| Introduction to the measurement process<br>Systematic and random measurement uncertainties/errors Noise and noise analysis<br>Determination of measurement uncertainty according to GUM<br>Fundamentals of applied statistics: distribution functions, estimation theory, hypothesis tests, error propagation<br>Equalisation calculation, regression analysis<br>Statistical design of experiments<br>Quality management                                                                                                                                                                                                                                                                                                                                     |                                                                                             |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                             |                   |                                                                        |
| After completing the module, students will have an overview of the fundamentals of quality management and process optimisation. Thanks to the practical knowledge acquired, students will be able to solve simple optimisation tasks using statistical design of experiments.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                             |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                             |                   |                                                                        |
| - E. Schrüfer: Elektrische Messtechnik (Hanser Verlag 2007), ISBN 978-3446409040<br>- W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall 1991), ISBN 978-0023805523<br>- O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag 1978), ISBN 978-3411001194<br>- N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons 1977), ISBN 978-0471017561 und 978-0471017578<br>- Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig 1974, im Bibliotheksbestand<br>- B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH, 2004), ISBN 978-3833010392 |                                                                                             |                   |                                                                        |

- G. Linß: Qualitätsmanagement für Ingenieure (Hanser Fachbuchverlag Leipzig 2005), ISBN 978-3446228214



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <ul style="list-style-type: none"> <li>• E. Schrüfer: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall)</li> <li>• O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag)</li> <li>• N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley &amp; Sons)</li> <li>• Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig</li> <li>• B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH)</li> <li>• G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <ul style="list-style-type: none"> <li>• E. Schrüfer: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall)</li> <li>• O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag)</li> <li>• N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley &amp; Sons)</li> <li>• Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig</li> <li>• B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH)</li> <li>• G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)</li> </ul> |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                      |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                            | Automated Road Vehicles: from Assistance to Autonomy |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                           | 2412620                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                        |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                                    | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                                              | Module owner      | Prof. Dr. Markus Maurer                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                     | 150                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                             | 56                                                   | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                          |                                                      |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                        | Written exam (60 min) or oral exam (30 min)          |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                               |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| <div>-probabilistic knowledge representation for driver assistance and vehicle guidance systems</div> <div>- radar-based and visual machine perception</div> <div>- machine situation detection and behavioural decision-making</div> <div>- human-machine-interaction</div> <div>- design and test of driver assistance and vehicle guidance systems</div>                                                      |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                          |                                                      |                   |                                                          |
| After completing this module, students will have basic knowledge of driver assistance systems and automated vehicles. They are familiar with the current state of the art in driver assistance systems and automated driving functions and know about the function-determining factors. The students are able to independently plan customer-value driver assistance systems and systems for vehicle automation. |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                       |                                                      |                   |                                                          |
| <div>- Handbook of Driver Assistance Systems; Basic Information, Components and Systems for Active Safety and Comfort; Editors: Winner, H., Hakuli, S., Lotz, F., Singer, C. (eds.); 1. Edition 2016 Springer; available free of charge for students via Springer-Link</div>                                                                                                                                     |                                                      |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                           |                                                      |                   |                                                          |
| The course “Automotive Systems Engineering” provides helpful background knowledge for this course; however, it is not a mandatory prerequisite for participation.                                                                                                                                                                                                                                                |                                                      |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| Only one of the three modules ET-IFR-42, ET-IFR-58, ET-IFR-62 can be chosen.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Hermann Winner (Hrsg.), Stephan Hakuli (Hrsg.), Gabriele Wolf (Hrsg.): Handbuch Fahrerassistenzsysteme Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort, Springer, 3. Auflage 2015, ISBN: 978-3658057336</li> <li>- R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111</li> <li>- M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964</li> <li>- S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Hermann Winner (Hrsg.), Stephan Hakuli (Hrsg.), Gabriele Wolf (Hrsg.): Handbuch Fahrerassistenzsysteme Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort, Springer, 3. Auflage 2015, ISBN: 978-3658057336</li> <li>- R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111</li> <li>- M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964</li> <li>- S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Integrated Circuits     |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2413280                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                         | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | only in the winter term | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1                       | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 3 / 5,0                 | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 150                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 42                      | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                         |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | oral exam (20 min)      |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                         |                   |                                                          |
| <p>The module provides an overview of the operation, design, and technology of integrated electronic circuits in microelectronics.</p> <ul style="list-style-type: none"><li>• Introduction</li><li>• Basic digital circuits</li><li>• MOS and CMOS</li><li>• Silicon wafer manufacturing</li><li>• MOSFET process technology</li><li>• Nanolithography</li><li>• Etching techniques and oxidation</li><li>• Design automation, design rules, and assembly techniques</li><li>• Back-end technologies</li><li>• Modern developments: Memory technologies</li></ul> |                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                         |                   |                                                          |
| After completing the module, students will be able to understand integrated circuits, their structure and mode of operation and design simple integrated circuits themselves. A further focus is on the methods of nanotechnology.                                                                                                                                                                                                                                                                                                                                 |                         |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                         |                   |                                                          |
| <p>Lecture slides and short script<br/>J.M.Rabaey, A.Chandrakasan, B. Nikolic, Digital Integrated Circuits<br/>Prentice Hall Electronics and VLSI Series, 2002 ISBN: 8120322576<br/>A. Schlachetzki, Integrierte Schaltungen, Teubner, 1978, (as copy at IHT) ISBN: 3-519-03070-5<br/>D. Widmann, H. Mader, H. Friedrich, Technologie Hochintegrierte Schaltungen, Springer, 1996<br/>ISBN: 3540593578<br/>W. Prost, Technologie der III/V Halbleiter, Springer, 1997 ISBN: 3540628045</p>                                                                         |                         |                   |                                                          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2,0        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <p>Vorlesungsfolien und Kurzschrift</p> <p>K.-H. Cordes, A. Waag, N. Heuck: Integrierte Schaltungen; Pearson Studium, 2010</p> <p>J.M.Rabaey, A.Chandrakasan, B. Nikolic, Digital Integrated Circuits Prentice Hall Electronics and VLSI Series, 2003, 1996</p> <p>A. Schlachetzki, Integrierte Schaltungen, Teubner, 1978, (als Kopie im IHT)</p> <p>D. Widmann, H. Mader, H. Friedrich, Technologie Hochintegrierte Schaltungen, Springer, 1996</p> <p>W. Prost, Technologie der III/V-Halbleiter, Springer, 1997</p> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1,0        | Exercise         | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| K.-H. Cordes, A. Waag, N. Heuck : Integrierte Schaltungen; Pearson Studium, 2010                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                          |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Packaging and Interconnection Technology |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2413390                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                          | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | only in the summer term                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                        | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 3 / 5,0                                  | Module owner      | Prof. Dr. Erwin Peiner                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 150                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 42                                       | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                          |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | oral exam (30 min)                       |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                          |                   |                                                          |
| <ul style="list-style-type: none"><li>- Open wiring, bread board, printed circuit board</li><li>- Thick film technologies, substrates, screen printing and pastes, thin film technology, photolithography</li><li>- Surface mount technology, components, housing forms, modern developments (TAB, BGA, flip chip, CSP, MCM)</li><li>- Power modules, special requirements</li><li>- Cooling, basics and problems, air cooling, liquid cooling</li><li>- Thermomechanical stresses and reliability, basics, examples</li><li>- Soldering</li><li>- Adhesive bonding</li><li>- Wire bonding</li><li>- Direct copper bonding</li><li>- Low-temperature joining technology</li></ul> |                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                          |                   |                                                          |
| <p>After completing the module electronic packaging, the students will have</p> <ul style="list-style-type: none"><li>- a basic understanding of the most important processes for assembling and joining electronic devices and components</li><li>- the ability to select suitable processes for packaging in the manufacture of semiconductor modules</li><li>- in-depth knowledge and practical experience in the use, analysis and evaluation of methods of electronic packaging</li></ul>                                                                                                                                                                                    |                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                          |                   |                                                          |
| <p>W. Scheel (Hrsg.): Baugruppenteknologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) ISBN: 3-341-01100-5</p> <p>H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik # Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01097-1</p> <p>H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik # Hybridträger (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01099-8</p> <p>M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiesbaden, 1991) ISBN: 3-528-06392-0</p>                                                                                                                                     |                                          |                   |                                                          |



J. H. Lau, "Recent Advances and Trends in Advanced Packaging," in IEEE Transactions on Components, Packaging and Manufacturing Technology, vol. 12, no. 2, pp. 228-252, Feb. 2022, doi: 10.1109/TCPMT.2022.3144461.

Y. Yang, L. Dorn-Gomba, R. Rodriguez, C. Mak and A. Emadi, "Automotive Power Module Packaging: Current Status and Future Trends," in IEEE Access, vol. 8, pp. 160126-160144, 2020, doi: 10.1109/ACCESS.2020.3019775.

Morris J.E. (2018) Nanopackaging: Nanotechnologies and Electronics Packaging. In: Morris J. (eds) Nanopackaging. Springer, Cham. [https://doi.org/10.1007/978-3-319-90362-0\\_1](https://doi.org/10.1007/978-3-319-90362-0_1)



|                                                                                                                                 |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                          |            |                  |                 |
|                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                    |            |                  |                 |
|                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                 | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                               |            |                  |                 |
| Unterlagen werden verteilt.                                                                                                     |            |                  |                 |
|                                                                                                                                 | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                               |            |                  |                 |
| W. Scheel (Hrsg.): Baugruppenteknologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) |            |                  |                 |
| H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik - Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994)                |            |                  |                 |
| H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik - Hybridträger (Verlag Technik, Berlin, Saulgau, 1994)                 |            |                  |                 |
| M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiesbaden, 1991)                                                                |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Semiconductor Technology |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2413420                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                          | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the summer term  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                        | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                  | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                       | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                          |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Oral exam 30 min         |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                          |                   |                                                          |
| <ul style="list-style-type: none"><li>- physical and chemical basics</li><li>- manufacturing of single crystals and wafers</li><li>- epitaxial crystal growth processes and crystal defects</li><li>- doping processes</li><li>- semiconductor measurement technology</li><li>- planar technology</li><li>- basics of photolithography, deposition processes for dielectrics and etching processes</li></ul>                                                                                                                                                                               |                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                          |                   |                                                          |
| After completing the semiconductor technology module, students have: <ul style="list-style-type: none"><li>• an understanding of the basic manufacturing technologies of semiconductors as well as components and integrated circuits made from them.</li><li>• the ability to recognize the principles of the most modern manufacturing processes in semiconductor technology and their modes of operation</li><li>• the ability to analyze and extrapolate trends in semiconductor technology developments</li></ul>                                                                     |                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                          |                   |                                                          |
| <ul style="list-style-type: none"><li>• Lecture transparencies</li><li>• Script in Englisch (H.-H. Wehmann and A. Schlachetzki)</li><li>• Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(Stuttgart, 1998) ISBN: 3-519-06167-8</li><li>• Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (Berlin, 1991) ISBN: 3-540-53873-9</li><li>• Werner Prost: Technologie der III/V-Halbleiter, Springer (Berlin, 1997) ISBN. 3-540-62804-5</li><li>• Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (Stuttgart, 2004) ISBN: 3-519-30149-0</li></ul> |                          |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                          |                   |                                                          |
| Language German or English                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                          |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Semiconductor Technology                                                                                                                                                                                                                                                                                                                          | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner (1998)<br>Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (1991)<br>Werner Prost: Technologie der III/V-Halbleiter, Springer (1997)<br>Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (2004)<br>Ausführliches Skript in Englisch Vorlesungsfolien |            |                  |                 |
| Semiconductor Technology                                                                                                                                                                                                                                                                                                                          | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| Übungsmaterial wird verteilt.                                                                                                                                                                                                                                                                                                                     |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                     | Optical Communications with Lab                      |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                    | 2415220                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                 |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                        | only in the winter term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                           | 1                                                    | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                     | 4 / 6,0                                              | Module owner      | Prof. Dr. Thomas Schneider                               |
| Workload (h)                                                                                                                                                                                                                                                                                                              | 180                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                      | 56                                                   | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                   |                                                      |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                              | Written exam (120 minutes) or oral exam (30 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                        |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                  |                                                      |                   |                                                          |
| <ul style="list-style-type: none"><li>- Optical fibers</li><li>- Dispersion, velocities of light</li><li>- Coherent modulation</li><li>- Coherent receiver</li><li>- Laser</li><li>- Optical amplifier</li><li>- Optoelectronic modulators</li><li>- Photodetectors</li><li>- Systems of optical communications</li></ul> |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                   |                                                      |                   |                                                          |
| After completing the module, the students understand the mode of operation and know the performance characteristics of different components of optical transmission links. They can design and dimension fibre-optic transmission links.                                                                                  |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                |                                                      |                   |                                                          |
| S. L. Chuang, Physics of Photonic Devices, Wiley & Sons, ISBN 9780470293195                                                                                                                                                                                                                                               |                                                      |                   |                                                          |

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|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|                                                                                                                                                            |     |            |         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------|---------|
|                                                                                                                                                            | 2,0 | Lecture    | german  |
| <b>Literature</b>                                                                                                                                          |     |            |         |
| <ul style="list-style-type: none"> <li>- Skript zur Vorlesung</li> <li>- S. L. Chuang, Physics of Optoelectronic Devices, John Wiley &amp; Sons</li> </ul> |     |            |         |
|                                                                                                                                                            | 1,0 | Exercise   | german  |
|                                                                                                                                                            | 1,0 | Laboratory | english |
| <b>Literature</b>                                                                                                                                          |     |            |         |
| Skript zum Praktikum                                                                                                                                       |     |            |         |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Optoelectronics                                             |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2415290                                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the summer term                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                                           | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                                                     | Module owner      | Prof. Dr. Wolfgang Kowalsky                              |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Written exam (90 min) or oral exam (30 min) or presentation |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                             |                   |                                                          |
| <div>- Propagation of electromagnetic waves in free space and in guiding structures</div> <div>- Refraction, reflexion, total reflexion at dielectric interfaces</div> <div>- Optical guiding in film and strip waveguides, mechanisms of losses</div> <div>- Optical modes and theoretical description</div> <div>- field distribution in step and gradient profiles, analogy to quantum mechanics</div> <div>- Periodic structures to distributed feedback: DFB, DBR</div> <div>- Electrooptical interaction, directional couplers</div> |                                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                             |                   |                                                          |
| After completion of the module students have gained knowledge in the functional mechanisms and the design of devices for integrated optics, particularly of waveguides. They are able to apply these competences in the analysis of optoelectronic systems with regard to device and circuit level and to qualify and optimize these systems.                                                                                                                                                                                              |                                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                             |                   |                                                          |
| K. J. Ebeling, Integrierte Optoelektronik, Springer, ISBN 3540546553                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                             |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|  |     |          |        |
|--|-----|----------|--------|
|  | 2,0 | Lecture  | german |
|  | 1,0 | Exercise | german |

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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Microwave Circuit Design 2 (Nonlinear Circuits)                                                                        |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2415340                                                                                                                | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                        | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the summer term                                                                                                | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                                                                                      | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 6 / 8,0                                                                                                                | Module owner      | Prof. Dr. Jörg Schöbel                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 240                                                                                                                    |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 84                                                                                                                     | Self studying (h) | 156                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                        |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | written examination (90 min) or oral examination (30 min) or homework assignments or semester project assignment (§ 4) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                        |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                        |                   |                                                          |
| <div>- Mixers, parametric calculation, modeling of active components</div> <div>- The Harmonic Balance method including a programming assignment for an exemplary implementation of the method</div> <div>- Radio frequency diodes (pn varactor, Schottky varactor, IMPATT diode), Gunn element</div> <div>- Frequency multipliers, harmonic mixers and oscillators, resonators and resonator coupling</div> <div>- Design of nonlinear microwave circuits using commercial design software</div>                              |                                                                                                                        |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                        |                   |                                                          |
| After completion of the module students have a deeper understanding of active nonlinear microwave circuits and of the relevant semiconductor devices, as well as of the measurement technology and characterization of nonlinear circuits. They have learned methods of analytical and numerical modeling and have gained practical experience in their implementation and usage. They are able to design nonlinear microwave circuits, such as mixers and oscillators and have put this into practice on a practical example. |                                                                                                                        |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                        |                   |                                                          |
| Pozar, Microwave Engineering, Wiley, ASIN B001QA4I9C Maas, Nonlinear Microwave and RF Circuits, Artech House, ISBN 1580534848                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |                   |                                                          |

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|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |



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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------|--------|
|                                                                                                                                                                                        | 2,0 | Lecture    | german |
| <b>Literature</b>                                                                                                                                                                      |     |            |        |
| <ul style="list-style-type: none"><li>- Skript zur Vorlesung</li><li>- Pozar, Microwave Engineering, Wiley</li><li>- Maas, Nonlinear Microwave and RF Circuits, Artech Hoise</li></ul> |     |            |        |
|                                                                                                                                                                                        | 2,0 | Exercise   | german |
|                                                                                                                                                                                        | 2,0 | Internship | german |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Antennas and Electromagnetic Radiation                  |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2415360                                                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                         | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the summer term                                 | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                                       | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 4 / 6,0                                                 | Module owner      | Prof. Dr. Jörg Schöbel                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 180                                                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 56                                                      | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                         |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (90 min) or oral exam (30 min) or homework |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                         |                   |                                                          |
| <ul style="list-style-type: none"><li>- electromagnetic theory founded on Maxwell's equations and respective calculation techniques (wave equation, solution of the inhomogeneous wave equation, source integrals, Huygens' principle, image theory, Hertzian dipole)</li><li>- basic antenna structures, characteristic parameters of antennas</li><li>- array antennas and beamforming, synthesis of antenna patterns</li><li>- aperture antennas, Fourier transformation, horn and slot antennas, parabolic antennas, Physical Optics</li><li>- wave propagation, diffraction limit of free-space propagation, static models, radar cross section</li><li>- antenna and RCS characterization methods</li><li>- modern state of the art and current research topics</li></ul> |                                                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                         |                   |                                                          |
| After completing the module, students will have an in-depth understanding of electromagnetic theory for radiation fields as well as a basic understanding of wave propagation and related phenomena (e.g. Radar cross section). They have become familiar with different types of antenna elements as well as array antennas and have a clear and well-founded theoretical understanding of their electromagnetic properties and their parameters. The students have gained first experiences in the use of modern 3D-EM simulation tools and modern RF measurement techniques and are able to acquire further in-depth knowledge in the application of these tools on their own.                                                                                               |                                                         |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                         |                   |                                                          |
| Unger, Hochfrequenztechnik in Funk und Radar, Teubner-Verlag, ISBN 3519300184<br>Unger, Elektromagnetische Theorie für die Hochfrequenztechnik, Hüthig-Verlag, ISBN 377851573X<br>Pozar, Microwave Engineering, Wiley, ASIN B001QA4I9C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                         |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                         |                   |                                                          |
| Prerequisites: Mathematics, Electromagnetic Fields, Fundamentals of Information Technology, Guided Electromagnetic Waves                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                         |                   |                                                          |



| <b>Related courses</b>                 |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Antennas and Electromagnetic Radiation | 1,0        | Exercise         | german          |
|                                        | 3,0        | Lecture          | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                               | Linear Microwave Circuit Design (including Laboratory Class)                                                           |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                              | 2415370                                                                                                                | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                        | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                  | only in the winter term                                                                                                | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                     | 1                                                                                                                      | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                               | 4 / 6,0                                                                                                                | Module owner      | Prof. Dr. Jörg Schöbel                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                        | 180                                                                                                                    |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                | 56                                                                                                                     | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                        |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                        | written examination (90 min) or oral examination (30 min) or homework assignments or semester project assignment (§ 4) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                        |                   |                                                          |
| <div>- Matching structures, binomial and Chebychev multisection transformers, Bode-Fano criterion</div> <div>- PIN diode, microwave switches and phase shifters</div> <div>- Bipolar transistor, HBT, FET, HEMT, amplifiers, LNA, power amplifiers</div> <div>- Design and realization of microwave filters</div> <div>- Design of linear microwave circuits using commercial design software</div> |                                                                                                                        |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                        |                   |                                                          |
| After completion of the module students have a deeper understanding of passive and active linear microwave circuits, especially filters and amplifiers. They are able to design linear microwave circuits and have used respective design procedures on practical examples.                                                                                                                         |                                                                                                                        |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                        |                   |                                                          |
| Pozar, Microwave Engineering, Wiley, ASIN B001QA4I9C Unger, Harth, Hochfrequenz-Halbleiterelektronik, Hirzel, ISBN 3777602353                                                                                                                                                                                                                                                                       |                                                                                                                        |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 1,0        | Internship       | german          |

|                                                                                                                                                                                 |     |          |        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|----------|--------|
|                                                                                                                                                                                 | 2,0 | Lecture  | german |
| <b>Literature</b>                                                                                                                                                               |     |          |        |
| <ul style="list-style-type: none"><li>- Skript zur VL</li><li>- Pozar, Microwave Engineering, Wiley</li><li>- Unger, Harth, Hochfrequenz-Halbleiterelektronik, Hirzel</li></ul> |     |          |        |
|                                                                                                                                                                                 | 1,0 | Exercise | german |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Radar Systems and Signal Processing                         |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2415450                                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the summer term                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                                           | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                                     | Module owner      | Prof. Dr. Jörg Schöbel                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 64                                                          | Self studying (h) | 86                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | oral exam (30 min) or written exam (60 min) or project work |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                             |                   |                                                          |
| <p>The module provides an overview of radar systems and their signal processing. Different radar concepts (pulse, FMCW, ...), their associated hardware, and the most important key terms and concepts of signal processing are considered. Automotive radar systems are emphasized.</p> <p>After completion of the module the students will have in-depth knowledge of radar system concepts in connection with the associated circuit concepts and signal processing and will be able to evaluate and conceptually design radar systems on this basis. Students have knowledge of the most important algorithms used in radar signal processing and have gained experience in the function and interaction of radar hardware and software. This extends from signal generation and signal acquisition to signal evaluation (range and velocity determination) and angle determination with array antennas. This enables the students to work on detailed questions in radar system development and to acquire the associated special knowledge independently.</p> |                                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                             |                   |                                                          |
| <p>Requirements: it is recommended to have completed the module “RF and Microwave Systems and Circuits” expected knowledge:</p> <ul style="list-style-type: none"><li>- introduction to RF circuits (S parameters, concept of matching)</li><li>- transmission line theory</li><li>- antenna and radio transmission basics (dipole antenna, antenna parameters, Friis transmission equation, link budget)</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                             |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 2,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                |                                                    |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                          | Nonlinear Photonics                                |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                         | 2415470                                            | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                      |                                                    | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                             | only in the winter term                            | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                | 1                                                  | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                          | 4 / 5,0                                            | Module owner      | Prof. Dr. Thomas Schneider                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                   | 150                                                |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                           | 56                                                 | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                        |                                                    |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                      | Written exam, 90 minutes, or oral exam, 30 minutes |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                             |                                                    |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                       |                                                    |                   |                                                          |
| <div>- Basics of linear optics</div> <div>- 2nd order nonlinear optical effects</div> <div>- 3rd order nonlinear optical effects</div> <div>- Nonlinear scattering</div> <div>- Optical telecommunications</div> <div>- Nonlinear effects in optical fibers</div> <div>- Suppression of nonlinear effects</div> <div>- Applications of nonlinear effects</div> |                                                    |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                        |                                                    |                   |                                                          |
| After a successful participation, the students know the main basics of nonlinear photonics and will be able to use them for the evaluation of optical systems and optical data transmission systems.                                                                                                                                                           |                                                    |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                     |                                                    |                   |                                                          |
| T. Schneider "#Nonlinear Optics in Telecommunications#", Springer Verlag                                                                                                                                                                                                                                                                                       |                                                    |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |



|                     |     |          |         |
|---------------------|-----|----------|---------|
| Nonlinear Photonics | 2,0 | Lecture  | english |
| Nonlinear Photonics | 2,0 | Exercise | english |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                            |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Electromagnetic Theory for Microwave Engineering                                                                           |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2415490                                                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                            | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | only in the winter term                                                                                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                                                                                                          | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 4 / 6,0                                                                                                                    | Module owner      | Prof. Dr. Jörg Schöbel                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 180                                                                                                                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 56                                                                                                                         | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                            |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | written examination 90 minutes or oral examination 30 minutes or homework assignments or semester project assignment (§ 4) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                            |                   |                                                          |
| <div>- Theory of time-harmonic electromagnetic fields (Maxwell's equations, wave equation, Poynting's theorem, uniqueness theorem, reciprocity)</div> <div>- Methods of calculation (vector potentials, Lorenz gauge, solution of the (in)homogeneous wave equation, source integrals, Green's function)</div> <div>- Eigenmodes of waveguides, surface waves, leaky waves</div> <div>- Radiation fields (Huygens' principle, image theory, Fresnel and Fraunhofer approximations)</div> <div>- Introduction to the numerical solution of electromagnetic problems (FDTD, method of moments, eigenmode expansion)</div> <div>- Exemplary implementation of solution methods in Matlab or Python</div> <div>- simulation of electromagnetic structures using commercial 3D-EM-software</div>                                                                                                                                                                                                                                                                                       |                                                                                                                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                            |                   |                                                          |
| <div>After completing the module, students will have in-depth knowledge and a well-founded conceptual understanding of the theory of electromagnetic waves with respect to the solution of the homogeneous wave equation (waveguide structures) as well as of the inhomogeneous wave equation (antennas). They have become familiar with different analytical and numerical solution methods for electromagnetic problems and exemplarily implemented selected methods as well as applied them in the context of commercial 3D-EM software. They will be able to select problem-adapted solution methods and to apply them competently to electromagnetic problems.</div> <div>According to the didactic concept of the course and the design of its individual parts, interdisciplinary qualifications are conveyed and practiced. In the context of assignments, colloquia and presentations these are scientific writing and documentation, scientific discussions and presentation techniques as well as teamwork in the laboratory or within team project assignments.</div> |                                                                                                                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                            |                   |                                                          |
| <div>Harrington, Time-harmonic Electromagnetic Fields, Wiley &amp; Sons, ISBN 047120806X</div> <div>Unger, Elektromagnetische Theorie für die Hochfrequenztechnik I + II, Hüthig, ISBN 377851573X, ISBN 3778515748</div> <div>Pozar, Microwave Engineering, Wiley &amp; Sons, ASIN B001QA4I9C</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                            |                   |                                                          |



| <b>Related courses</b>                 |            |                    |                 |
|----------------------------------------|------------|--------------------|-----------------|
| <b>Rules for the choice of courses</b> |            |                    |                 |
|                                        |            |                    |                 |
| <b>Compulsory attendance</b>           |            |                    |                 |
|                                        |            |                    |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b>   | <b>Language</b> |
|                                        | 2,0        | Lecture            | german          |
|                                        | 1,0        | Exercise           | german          |
|                                        | 1,0        | Practical exercise | german          |

|                                                                                                                                                                                                                                                                                                  |                                             |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                            | Linear photonics with practical course      |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                           | 2415500                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                        |                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                               | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                  | 1                                           | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                            | 6 / 8,0                                     | Module owner      | Prof. Dr. Thomas Schneider                               |
| Workload (h)                                                                                                                                                                                                                                                                                     | 240                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                             | 84                                          | Self studying (h) | 156                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                        | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                               | Lab work                                    |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| Ray optics, wave optics, Fourier optics, electromagnetic optics, quantum optics with practical experiments on: lenses, imaging, refraction, diffraction, interferometers, determination of optical constants, polarisation, Fourier optics, holography, laser, waveguide optics, quantum optics. |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| After completing the module, the students know the essential fundamentals of modern photonics and can apply this knowledge to the assessment, design and simulation of photonic systems. Through the practical experiments offered, the students gain additional practical experience.           |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| B.E.A. Saleh, M.C. Teich, Fundamentals of Photonics, (Wiley Series in Pure and Applied Optics)                                                                                                                                                                                                   |                                             |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 2,0        | Exercise         | german          |

|                                                                                                |     |            |        |
|------------------------------------------------------------------------------------------------|-----|------------|--------|
|                                                                                                | 2,0 | Internship | german |
| <b>Literature</b>                                                                              |     |            |        |
| B.E.A. Saleh, M.C. Teich, Fundamentals of Photonics, (Wiley Series in Pure and Applied Optics) |     |            |        |

| Title                                                                                                                                                                                                                                                                                                                                                                                | Communication Networks for Engineers                |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                               | 2416490                                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                            |                                                     | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                   | only in the winter term                             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                      | 1                                                   | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                | 3 / 5,0                                             | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                         | 150                                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                 | 42                                                  | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                              |                                                     |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                         | Written exam (90 minutes) or oral exam (30 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                   |                                                     |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                             |                                                     |                   |                                                          |
| * Basic network topologies and protocol architectures<br>* Transmission systems and multiplexing methods<br>* Selected protocol mechanisms<br>* LAN protocols<br>* Basics of the Internet and the IP protocol<br>* Routing in the Internet<br>* The TCP protocol and its performance evaluation<br>* High-speed networks (MPLS, Ethernet and optical networks)<br>* Network security |                                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                              |                                                     |                   |                                                          |
| After completing this module, students have basic knowledge of architectures and protocol standards of communications networks and are familiar with the principles of signalling. The acquired fundamentals enable them to analyze and evaluate new protocols and switching technology procedures.                                                                                  |                                                     |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                           |                                                     |                   |                                                          |
| W. Stallings, Data and Computer Communications, Pearson Prentice Hall, 2004, ISBN: 0-13-183311-1 #<br>B. Mukherjee, Optical WDM networks, Springer, 2006, ISBN: 0-387-29055-9 #<br>J. F. Kurose und K. W. Ross, Computer Networking: A Top-Down Approach Featuring the Internet, Addison Wesley, 2005, ISBN: 0-321-26976-4                                                           |                                                     |                   |                                                          |

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|------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                     |            |                  |                 |
|                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                               |            |                  |                 |
|                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                            | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                          |            |                  |                 |
| * Skript<br>* J.F. Kuruse und K.W. Ross, Computernetze<br>* W. Stallings, Data and Computer Communications |            |                  |                 |
|                                                                                                            | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                          |            |                  |                 |
| * Skript<br>* J.F. Kuruse und K.W. Ross, Computernetze<br>* W. Stallings, Data and Computer Communications |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Network Security                            |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2416530                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                           | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3 / 5,0                                     | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>- Mathematical foundations of cryptology and information security</li><li>- Functions of public and secret key cryptology</li><li>- Authentication and data security protocols</li><li>- Current applications and standards of IP network security</li><li>- Current applications and standards of wireless network security</li><li>- Network commerce and payment systems</li><li>- Selected current advanced network security topics</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                          |
| After completing the module, the students are able to use the acquired basic knowledge of current cryptology to design basic crypto systems and assess their level of security.<br>The students have acquired the ability, by means of the common techniques of protocols and standards of network security, to analyse fundamental features of a security design in current network environments, and apply basic design methods of network security.                                  |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>• W. Adi, lecture notes and exercises</li><li>• William Stallings, Network Security Essentials: Applications and Standards, 3rd Edition, Prentice Hall, © 2007, ISBN-10: 0-13-238033-1</li><li>• Charlie Kaufman, Radia Perlman, Mike Speciner, Network Security: Private Communication in a Public World (2nd edition), Prentice Hall, 2002, ISBN-10: 0130460192</li></ul>                                                                       |                                             |                   |                                                          |

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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                          | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <ul style="list-style-type: none"> <li>W. Adi, Vorlesungsfolien und Übungen. William Stallings, Network Security Essentials: Applications and Standards, 3rd Edition, Prentice Hall, © 2007, ISBN-10: 0-13-238033-1</li> <li>Charlie Kaufman, Radia Perlman, Mike Speciner, Network Security: Private Communication in a Public World (2nd edition), Prentice Hall, 2002, ISBN-10: 0130460192</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                          | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                         | Performance Evaluation of Communications Network                                 |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                        | 2416580                                                                          | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                     |                                                                                  | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                            | only in the summer term                                                          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                               | 1                                                                                | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                         | 3 / 5,0                                                                          | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                  | 150                                                                              |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                          | 42                                                                               | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                       |                                                                                  |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                  | Written exam (90 min) or oral exam (30 min), depending on number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                            |                                                                                  |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                      |                                                                                  |                   |                                                          |
| <ul style="list-style-type: none"><li>- Modeling of stochastic processes</li><li>- Theory of Markoff chains</li><li>- Processes and characteristics in communication systems</li><li>- Multiservice communication systems</li><li>- M/G/1 queueing systems and priorities</li><li>- Basics of stochastic simulation</li></ul> |                                                                                  |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                       |                                                                                  |                   |                                                          |
| <ul style="list-style-type: none"><li>- Upon completion of this module, students will have a basic understanding of modeling stochastic processes in communication systems.</li><li>- Based on the introduced process characteristics, they are able to evaluate and compare systems, and to form their own models.</li></ul> |                                                                                  |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                    |                                                                                  |                   |                                                          |
| Lecture notes<br>L. Kleinrock, Queuing Systems - Volume I: Theory, John Wiley & Sons, New York, 1975, ISBN: 0-471-49110-1<br>A. Leon-Garcia: Probability and Random Processes for Electrical Engineering, Addison-Wesley, 1989, ISBN: 0-201-12906-X                                                                           |                                                                                  |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                        |                                                                                  |                   |                                                          |
| Electrical Engineering: Knowledge of the content of the Statistics module is assumed.<br>Computer Science Minor: Recommended prior knowledge is provided in the Introduction to Stochastics module or Statistics module. Information Systems Engineering: knowledge of the content of the Statistics module is assumed.       |                                                                                  |                   |                                                          |



|                                                                                                                         |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                  |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                  |            |                  |                 |
|                                                                                                                         |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                            |            |                  |                 |
|                                                                                                                         |            |                  |                 |
| <b>Name of the course</b>                                                                                               | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                         | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                       |            |                  |                 |
| #Skript<br>L. Kleinrock, Queuing Systems<br>A. Leon-Garcia, Probability and Random Processes for Electrical Engineering |            |                  |                 |
|                                                                                                                         | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                       |            |                  |                 |
| Skript<br>L. Kleinrock, Queuing Systems<br>A. Leon-Garcia, Probability and Random Processes for Electrical Engineering  |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Advanced Topics in Security                  |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2416600                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                            | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 3 / 5,0                                      | Module owner      | Dr. Vasileios Prevelakis                                 |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 42                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |
| 1. Network Security, network threats (e.g. MAC layer)firewalls, intrusion detection, honeypots virtual private networks, security policy<br>2. System Security, threats (buffer overflow, race conditions, privilege escalation), classical access control, process containment (Virtual Machines, runtime enforcement, etc.)<br>3. Software security, secure design, run time security Privacy<br>4. Advanced Security protocols: Voting Systems, e-Cash systems, Vehicular Security, others ...<br>5. Recent topics in Cryptography, Modern trends in cryptography, selected recent topics and discussions |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| The students are introduced to contemporary advanced topics in security systems and technology. They are able to analyze, assess and design security systems and their respective components.                                                                                                                                                                                                                                                                                                                                                                                                                |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Would be offered in the lecture time                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                              |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                              |                   |                                                          |
| Prerequisite: a course on Cryptology Design Fundamentals                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |

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|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Information Technologies for Social Good    |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2416720                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1                                           | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 3 / 5,0                                     | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | oral exam (30 min) or written exam (90 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| Disaster management of critical IT infrastructures<br>Prediction and information models for disaster management<br>Communication network systems for first responders<br>Bridging the digital divide<br>Low cost network systems for developing countries<br>Social networking for social good<br>IT systems to address climate change<br>Fundamentals of privacy and anonymity<br>Cryptography and privacy<br>Green farming<br>Smart farm animals<br>Technologies for domestic animals<br>Technologies for wild animals and preservation                                          |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             |                   |                                                          |
| This class is designed for students who are interested in studying the successful deployments and the potential use of information technologies in various topics that are essential for social good, including but not limited to disaster management, broadband and digital divide, social resilience, privacy, environmental sustainability, and animal welfare.<br>After completion of this module the students own deep knowledge about topical research subjects in this area. They are able to analyze, assess and design upcoming systems and their respective components. |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| Selected scientific publications<br>Book: Advanced ICTs for Disaster Management and Threat Detection: Collaborative and Distributed Frameworks, Edited by Asimakopoulou, Eleana, IGI Press 2010.<br>Book: Smart Sensing Technology for Agriculture and Environmental Monitoring, Edited by Subhas Chandra, Springer 2012.                                                                                                                                                                                                                                                          |                                             |                   |                                                          |

Book: More playful user interfaces, Interfaces that Invite Social and Physical Interactions, Edited by Anton Nijholt, Springer 2015.

**Remark**

Prerequisites: The students are expected to have already taken courses in networking and in particular in the architecture and protocols in the Internet, broadband networks, protocols and software engineering, as well as communication technologies, such as fiber, traditional wireline and wireless networks.



**Related courses**

**Rules for the choice of courses**

**Compulsory attendance**

| Name of the course | SWS | Eventtype | Language |
|--------------------|-----|-----------|----------|
|                    | 1,0 | Exercise  | english  |
|                    | 2,0 | Lecture   | english  |

**Literature**

Buch: Advanced ICTs for Disaster Management and Threat Detection: Collaborative and Distributed Frameworks, Edited by Asimakopoulou, Eleana, IGI Press 2010.  
 Buch: Smart Sensing Technology for Agriculture and Environmental Monitoring, Edited by Subhas Chandra, Springer 2012.  
 Buck: More playful user interfaces, Interfaces that Invite Social and Physical Interactions, Edited by Anton Nijholt, Springer 2015.

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | New Architecture and Protocols in Communication Networks |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2416760                                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                          | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | only in the summer term                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1                                                        | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 3 / 5,0                                                  | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 150                                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 42                                                       | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                          |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Written exam (90 min) or oral exam (30 min)              |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                          |                   |                                                          |
| <ul style="list-style-type: none"><li>• Introduction to broadband communication</li><li>• Broadband access networks</li><li>• Optical Networks</li><li>• Control and management of broadband networks</li><li>• Wireless broadband networks</li><li>• Applications of broadband networks</li></ul>                                                                                                                                                                                                     |                                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                          |                   |                                                          |
| After completing this module, students will have in-depth knowledge of architectures and signaling protocols of new architecture and protocols in advanced communication networks, including the access networks, core and backone networks, optical transport networks, wireless networks and virtual private networks, such as data center networks and campus networks. The fundamentals learned enable students to design, analyze and evaluate new protocols, services and network architectures. |                                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                          |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                          |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |



|                                                                    |     |          |                |
|--------------------------------------------------------------------|-----|----------|----------------|
|                                                                    | 2,0 | Lecture  | german         |
| <b>Literature</b>                                                  |     |          |                |
| Include latest research papers, tutorials and industrial standards |     |          |                |
|                                                                    | 1,0 | Exercise | english german |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Network-Security                             |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2416770                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                            | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 3 / 5,0                                      | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 42                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |
| The lecture gives a broad introduction to network security, including foundations of cryptography, message integrity, authentication, privacy and anonymity, application layer security, secure network protocols, security in the physical layer, as well as broader aspects security aspects related to reliability and safety. It also discusses relevant topics in various application domains, such as (i) security in next generation mobile networks, (ii) satellite network security; (iii) security in the compute continuum of IoT, edge and cloud computing; (v) security functions within the network management; (vi) physical layer security in optical and wireless networks. |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| On finishing this module the students have a survey of the theoretical principles of cryptography. They are able to analyze basic cryptographic systems and are able to design basic electronic security systems.                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Material provided to students in StudIP, including the references noted within                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|                                                                                |     |          |        |
|--------------------------------------------------------------------------------|-----|----------|--------|
|                                                                                | 2,0 | Lecture  | german |
| <b>Literature</b>                                                              |     |          |        |
| Material provided to students in StudIP, including the references noted within |     |          |        |
|                                                                                | 1,0 | Exercise | german |
| <b>Literature</b>                                                              |     |          |        |
| Material provided to students in StudIP, including the references noted within |     |          |        |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Advanced Topics in Network Engineering |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2416780                                | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                        | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | only in the winter term                | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1                                      | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 3 / 5,0                                | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 150                                    |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 42                                     | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                        |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                       | oral exam (30 min)                     |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                        |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                        |                   |                                                          |
| <ul style="list-style-type: none"><li>• Cross Layer Design</li><li>• All-IP networks</li><li>• Integration of IP and Optical</li><li>• Inter-domain Routing</li><li>• Networks for Data Centers, Storage and Grid Computing</li><li>• Economics, Standards and Regulations in Telecommunications</li><li>• Applications of Networking in Energy, Automation and Health Care</li><li>• Research Literature, Papers and Surveys</li></ul>                                            |                                        |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                        |                   |                                                          |
| Upon completion of this module, students will have in-depth knowledge of the state of the art and future research topics in the field of architectures and protocols in communication networks. The foundations in this class will help students to better understanding the interaction of complex multi-layered and heterogeneous network architectures and to learning how to engineer the network.                                                                             |                                        |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                        |                   |                                                          |
| G. Camarillo, M. García-Martín, The 3G IP Multimedia Subsystem (IMS): Merging the Internet and the Cellular Worlds, John Wiley & Sons, 2004, ISBN: 978-0-470-87156-0<br>F. Travostino, J. Membretti, G. Karmous-Edwards (Eds.), Grid Networks: Enabling Grids with Advanced Communication Technology, John Wiley & Sons, 2006, ISBN: 978-0-470-01748-7<br>K. M. Sivalingam and T. Znati (Eds), Wireless Sensor Networks, Kluwer Academic Publishers, 2005, ISBN: 978-1-4020-7883-5 |                                        |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                        |                   |                                                          |
| Knowledge of the content of the module Communication Networks are required.                                                                                                                                                                                                                                                                                                                                                                                                        |                                        |                   |                                                          |



|                                                                    |            |                  |                 |
|--------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                             |            |                  |                 |
| <b>Rules for the choice of courses</b>                             |            |                  |                 |
|                                                                    |            |                  |                 |
| <b>Compulsory attendance</b>                                       |            |                  |                 |
|                                                                    |            |                  |                 |
| <b>Name of the course</b>                                          | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                    | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                  |            |                  |                 |
| Include latest research papers, tutorials and industrial standards |            |                  |                 |
|                                                                    | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                  |            |                  |                 |
| Include latest research papers, tutorials and industrial standards |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                       | Numerical Calculation of Radiation Properties |                   |                                                               |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2419070                                       | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                               | Language          | german                                                        |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the summer term                       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                                             | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                       | 3 / 5,0                                       | Module owner      |                                                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                                           |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                        | 42                                            | Self studying (h) | 108                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                     |                                               |                   |                                                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                | Written exam (60 min) or oral exam (30 min)   |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                          |                                               |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                               |                   |                                                               |
| <div>- quantitative description of radiation properties by special numerical calculation methods</div> <div>- theoretical concepts of mainstream methods (FE, FD, MoM) and newer approaches (i.a. wavelets)</div> <div>- criteria of bandwidth and complexity of boundary conditions</div> <div>- practical sample applications from EMC (absorption in technical materials and biological tissue, shielding and antenna development)</div> |                                               |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                     |                                               |                   |                                                               |
| The students are able to specify suited numerical solution procedures for electromagnetic radiation problems. The underlying approaches of the procedures are understood, as well as the herefrom resulting limits for the application and potential sources of error.                                                                                                                                                                      |                                               |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                               |                   |                                                               |
| #Arnulf Kost, Numerische Methoden in der Berechnung elektromagnetischer Felder, Springer-Verlag, Berlin, 1994, ISBN 3-540-55005-4 #<br>Matthew N.O. Sadiku, Numerical Techniques in Electromagnetics, CRC Press, Boca Raton, 2001, ISBN 0-8493-1395-3                                                                                                                                                                                       |                                               |                   |                                                               |

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|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|  |     |          |        |
|--|-----|----------|--------|
|  | 2,0 | Lecture  | german |
|  | 1,0 | Exercise | german |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Electromagnetic Compatibility               |                   |                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2419120                                     | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                             | Language          | german                                                        |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                           | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3 / 5,0                                     | Module owner      | Prof. Dr. Thomas Kleine-Ostmann<br>Dr. Harald Spieker         |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                         |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 42                                          | Self studying (h) | 108                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written exam (60 min) or oral exam (30 min) |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                               |
| <ul style="list-style-type: none"><li>• Terms and definitions of EMC</li><li>• Sources of interference and disturbance variables, immunity of susceptible devices #</li><li>• Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference #</li><li>• Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection #</li><li>• Legal basis, product liability, standardization #</li><li>• EMC test engineering #</li><li>• Electromagnetic compatibility of biological systems</li></ul> |                                             |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                               |
| The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able assess the EMC product safety by failure mechanisms.    |                                             |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                               |
| <ul style="list-style-type: none"><li>- Lecture notes</li><li>- Joachim Franz, EMV – Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X</li><li>- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1</li><li>- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9</li></ul>                                                                                                                                                                                                                                 |                                             |                   |                                                               |





| <b>Related courses</b>                                                              |            |                  |                 |
|-------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>                                              |            |                  |                 |
| Either this module or "Electromagnetic Compatibility with Seminar" can be selected. |            |                  |                 |
| <b>Compulsory attendance</b>                                                        |            |                  |                 |
|                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Electromagnetic Compatibility                                                       | 2,0        | Lecture          | german          |
| Electromagnetic Compatibility                                                       | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Electromagnetic Compatibility with Seminar                        |                   |                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2419130                                                           | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                   | Language          | english german                                                |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | only in the winter term                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1                                                                 | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 5 / 6,0                                                           | Module owner      | Prof. Dr. Thomas Kleine-Ostmann                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 180                                                               |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 70                                                                | Self studying (h) | 110                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                   |                                                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Written exam (60 min) or oral exam, presentation of seminar topic |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                   |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                   |                   |                                                               |
| <ul style="list-style-type: none"><li>- Terms and definitions of EMC</li><li>- Sources of interference and disturbance variables, immunity of susceptible devices</li><li>- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference</li><li>- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection</li><li>- Legal basis, product liability, standardization</li><li>- EMC test engineering</li><li>- Electromagnetic compatibility of biological systems</li><li>- Current EMC issues presented in seminar talks</li></ul>                                                                    |                                                                   |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                   |                                                               |
| The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able to assess the EMC product safety by failure mechanisms. The students are able to investigate current EMC issues autonomously, structure and present them to an audience. |                                                                   |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                   |                   |                                                               |
| <ul style="list-style-type: none"><li>- continuously updated script handout</li><li>- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X</li><li>- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1</li><li>- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9</li></ul>                                                                                                                                                                                                                                                                                                                            |                                                                   |                   |                                                               |



|                                                                                                                                                                                                                            |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                     |            |                  |                 |
| You can either choose Electromagnetic Compatibility with Seminar <b>or</b> Electromagnetic Compatibility (without seminar). The seminar can also be attended in the summer semester after having attended the EMC lecture. |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Electromagnetic Compatibility                                                                                                                                                                                              | 2,0        | Lecture          | german          |
| Teacher training college EMC                                                                                                                                                                                               | 2,0        | Seminar          | english         |
| Electromagnetic Compatibility                                                                                                                                                                                              | 1,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                     |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Analog Integrated Circuits with Lab |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2420140                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                     | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the summer term             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                   | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 6 / 8,0                             | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 240                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 84                                  | Self studying (h) | 156                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                     |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Oral exam (30 min)                  |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                     |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                     |                   |                                                          |
| <p>All modern mobile communications applications (e.g., GSM, WLAN, GPS, Bluetooth, DECT, etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are increasingly being integrated into low-cost CMOS technology, resulting in significant differences from the classic design of high-frequency circuits based on discrete components. The lecture provides an introduction to the design of analog, integrated CMOS mobile communications receiver circuits.</p> <p>The lecture is divided into the following chapters:</p> <ul style="list-style-type: none"><li>• High-frequency amplifier circuits</li><li>• Simulation of electronic noise</li><li>• Low-noise input amplifiers in CMOS</li><li>• Mixer circuits</li><li>• HPhase-locked loops (PLLs)</li><li>• Voltage-controlled oscillators</li></ul>                                                                                                                                                                                                                        |                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                     |                   |                                                          |
| <p>After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).</p> <p>They will acquire fundamental knowledge in the use of the Spectre-RF design tool, which is widely used in industry for the design of analog integrated circuits.</p> <p>In accordance with the didactic concept of the course and the structure of the individual components, interdisciplinary skills are taught and practiced. These include scientific writing and documentation, conversation</p> |                                     |                   |                                                          |

and presentation techniques, and teamwork in the laboratory or on projects, which are covered in assignments, colloquia, and final presentations.

#### Literature

# Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press

#### Remark

For the Master's degree programs in Electrical Engineering, Industrial Engineering Electrical Engineering, and Information Systems Engineering



| Related courses                                                                   |     |            |          |
|-----------------------------------------------------------------------------------|-----|------------|----------|
| Rules for the choice of courses                                                   |     |            |          |
| Requirements for this module: circuit technology ( <i>Schaltungstechnik</i> , ST) |     |            |          |
| Compulsory attendance                                                             |     |            |          |
|                                                                                   |     |            |          |
| Name of the course                                                                | SWS | Eventtype  | Language |
| Analog Integrated Circuits (2013)                                                 | 1,0 | Exercise   | english  |
| Analog Integrated Circuits (2013)                                                 | 1,0 | Internship | english  |
| Analog Integrated Circuits (2013)                                                 | 2,0 | Lecture    | english  |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Analog Integrated Circuits |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2420150                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                          | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                    | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                         | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam 30 min           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                   |                                                          |
| <p>All modern mobile radio applications (e.g. GSM, WLAN, GPS, Bluetooth, Dect. etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are increasingly being integrated in low-cost CMOS technology, which results in significant differences to the classic design of high-frequency circuits based on discrete components. The lecture gives an introduction to the design of analog, integrated CMOS mobile radio receiver circuits.</p> <p>The lecture is divided into the following chapters:</p> <ul style="list-style-type: none"><li>- High frequency amplifier circuits</li><li>- Simulation of electronic noise</li><li>- Low-noise input amplifiers in CMOS</li><li>- Mixer circuits</li><li>- Phase-locked loops (PLLs)</li><li>- Voltage-controlled oscillators</li></ul> |                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| <p>After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                   |                                                          |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits" Cambridge University Press                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |



| <b>Related courses</b>                            |            |                  |                 |
|---------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>            |            |                  |                 |
| Prerequisite for this module: Circuit Design (ST) |            |                  |                 |
| <b>Compulsory attendance</b>                      |            |                  |                 |
|                                                   |            |                  |                 |
| <b>Name of the course</b>                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Analog Integrated Circuits (2013)                 | 1,0        | Exercise         | english         |
| Analog Integrated Circuits (2013)                 | 2,0        | Lecture          | english         |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Integrated Circuits for Biomedical Applications |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2420190                                         | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                 | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the winter term                         | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                               | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                         | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                             |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                                              | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                 |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam (30 min) or written exam (90 min)     |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                 |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                 |                   |                                                          |
| <ul style="list-style-type: none"><li>- Introduction to biomedical applications</li><li>- Biosensing principles (physical, electrical and electrochemical)</li><li>- Basic biomedical circuits: transimpedance and instrumentation amplifiers, oscillators, ADCs/DACs</li><li>- Basic circuits for Power Management (DCDC, LDO, Rectifier)</li><li>- Self-powering and energy storage (e.g. biofuel cell sensing, energy harvesting)</li><li>- Wireless Power Transfer (WPT) for implantable devices</li><li>- Circuits for ultra-low power data transmission</li><li>- Circuits for electrochemical sensing (potentiometric and amperometric)</li><li>- Examples of potentiometric biosensors (pH, K+, Na+, Ca+ etc) and iontophoresis</li><li>- Circuits for Impedance Spectroscopy</li><li>- Radar-based Imaging for Breast Cancer Detection</li><li>- Circuits for Electrical Impedance Tomography</li><li>- Resonance-based dielectric sensors (e.g. for glucose detection)</li><li>- Circuits for cochlear implants</li></ul> |                                                 |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                 |                   |                                                          |
| Upon completion of this module, the students will acquire knowledge about integrated circuits for various biomedical applications and obtain a deep understanding about circuit techniques for design of analog integrated circuits for biomedical applications (e.g. HF-oscillators for glucose sensing).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |
| “Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems”, Rahul Sarpeshkar, Cambridge University Press, 2010<br>“Power Management Integrated Circuits (Devices, Circuits, and Systems)”, M. Hella, P. Mercier, CRC Press, 2016<br>“Introduction to Biosensors From Electric Circuits to Immunosensors”, J.-Y. Yoon, Springer 2016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |





|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                            | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
| Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems, Rahul Sarpeshkar, Cambridge University Press, 2010<br>Power Management Integrated Circuits (Devices, Circuits, and Systems), M. Hella, P. Mercier, CRC Press, 2016<br>Introduction to Biosensors From Electric Circuits to Immunosensors, J.-Y. Yoon, Springer 2016 |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Exercise         | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
| Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems, Rahul Sarpeshkar, Cambridge University Press, 2010<br>Power Management Integrated Circuits (Devices, Circuits, and Systems), M. Hella, P. Mercier, CRC Press, 2016<br>Introduction to Biosensors From Electric Circuits to Immunosensors, J.-Y. Yoon, Springer 2016 |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Modelling and Simulation of Mobile Radio Systems |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2424400                                          | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                  | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the summer term                          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4 / 5,0                                          | Module owner      | Prof. Dr. Thomas Kürner                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                              |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 56                                               | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                  |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | oral exam (20 min) or written exam (90 min)      |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Colloquium or lab journal                        |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                  |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                  |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                  |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                  |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                  |                   |                                                          |
| Lecture notes<br>M. C. Jeruchim, P. Balaban, K. S. Shanmugan, Simulation of Communication Systems - Modeling, Methodology and Techniques, Kluwer 2000<br>R. Vaughan, J. B. Andersen, Channels, Propagation and Antennas for Mobile Communications, IEE Electromagnetic Waves Series 2003<br>J. G. Proakis, M. Saleh, Grundlagen der Kommunikationstechnik, Pearson Studium, 2. Auflage, 2004<br>M. Pätzold, Mobilfunkkanäle - Modellierung, Analyse und Simulation, Vieweg 1999<br>O. Beucher, MATLAB und Simulink, Pearson 2002<br>M. Schiff, Introduction to Communications Simulation, Artech House 2006<br>P. Stoica, R. Moses, Spectral Analysis of Signals, Pearson 2005 |                                                  |                   |                                                          |



|                                 |     |           |          |
|---------------------------------|-----|-----------|----------|
| Related courses                 |     |           |          |
| Rules for the choice of courses |     |           |          |
|                                 |     |           |          |
| Compulsory attendance           |     |           |          |
|                                 |     |           |          |
| Name of the course              | SWS | Eventtype | Language |

|                                                                                           |     |            |        |
|-------------------------------------------------------------------------------------------|-----|------------|--------|
|                                                                                           | 2,0 | Laboratory | german |
| <b>Literature</b>                                                                         |     |            |        |
| siehe Vorlesung                                                                           |     |            |        |
|                                                                                           | 2,0 | Lecture    | german |
| <b>Literature</b>                                                                         |     |            |        |
| Skript<br>M.C.Jeruchim, P.Balaban, K.S.Shanmugan: Simulation of Communications - Modeling |     |            |        |

| Title                                                                                                                                                                                                                                                                                                                                                                                       | Planning of Terrestrial Radio Networks              |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                      | 2424410                                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                   |                                                     | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                          | only in the summer term                             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                             | 1                                                   | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                       | 4 / 5,0                                             | Module owner      | Prof. Dr. Thomas Kürner                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                | 150                                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                        | 56                                                  | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                     |                                                     |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                | Oral exam (20 minutes) or written exam (90 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                          | Colloquium or lab journal                           |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                    |                                                     |                   |                                                          |
| Introduction<br>Radio propagation models<br>Coverage planning<br>Planning cellular networks<br>General principles of cellular network planning<br>GSM radio network planning<br>UMTS radio network planning<br>Planning OFDMA networks<br><br>As part of the computer exercise, an introduction to the operation and handling of a radio planning tool                                      |                                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                     |                                                     |                   |                                                          |
| After completing the module, students will have an understanding of the essential processes and interrelationships involved in planning terrestrial radio networks and will have acquired knowledge of the data required for this purpose and, in particular, the algorithms, models and methods used. They will be able to solve planning tasks independently using a radio planning tool. |                                                     |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                  |                                                     |                   |                                                          |
| <ul style="list-style-type: none"><li>• Lecture notes (German and English)</li><li>• C. Lüders, Mobilfunksysteme, Vogel-Verlag 2001 #</li><li>• N. Geng, W. Wiesbeck, Planungsmethoden für die Mobilkommunikation, Springer-Verlag 1998</li><li>• J. Laiho, A. Wacker, T. Novosad, Radio Network Planning and Optimisation for UMTS, Wiley 2002</li></ul>                                   |                                                     |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                      |                                                     |                   |                                                          |
| This Master's module is also suitable for Bachelor students.                                                                                                                                                                                                                                                                                                                                |                                                     |                   |                                                          |



|                                                                                                                                                                                                                                                                                    |            |                  |                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                             |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                                                                                                                    |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                       |            |                  |                 |
|                                                                                                                                                                                                                                                                                    |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                          | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                    | 2,0        | Laboratory       | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                  |            |                  |                 |
| siehe Vorlesung                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                    | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                  |            |                  |                 |
| Skript in deutscher und englischer Sprache<br>C.Lüders, Mobilfunksysteme, Vogel-Verlag 2001<br>N.Geng, W.Wiesbeck, Planungsmethoden für die Mobilkommunikation, Springer-Verlag 1998<br>J.Laiho, A.Wacker, T.Novosad, Radio Network Planning and Optimisation for UMTS, Wiley 2002 |            |                  |                 |

|                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                        | Fundamentals of Mobile Radio Communications |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                       | 2424490                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                    |                                             | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                           | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                              | 1                                           | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                        | 4 / 5,0                                     | Module owner      | Prof. Dr. Thomas Kürner                                  |
| Workload (h)                                                                                                                                                                                                                                                                                 | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                         | 56                                          | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                    | Oral exam (20 min) or written exam (90 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
| 1. Introduction<br>2. Wave Propagation<br>3. Radio Transmission<br>4. Media Access<br>5. 3GPP Wireless Systems<br>6. IEEE 802 Wireless Systems                                                                                                                                               |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| The lecture provides the basics in the areas of the air interface of mobile communication systems. Students will acquire knowledge on the structure and functionality of cellular and wireless local area networks.                                                                          |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| • Lecture notes<br>• C. Lüders, Mobilfunksysteme, Vogel-Verlag 2001<br>• # J. Schiller, Mobilkommunikation, Addison-Wesley 2000<br>• N. Geng, W. Wiesbeck, Planungsmethoden für die Mobilkommunikation, Springer-Verlag 1998 #<br>• A. Molisch, Wireless Communications, Addison-Wesley 2005 |                                             |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| This Master's module is also suitable for Bachelor students.                                                                                                                                                                                                                                 |                                             |                   |                                                          |



|                                                                                                                                                                                                                                                                         |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                  |            |                  |                 |
|                                                                                                                                                                                                                                                                         |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                         |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                               | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                         | 1,5        | Exercise         | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                       |            |                  |                 |
| siehe Vorlesung                                                                                                                                                                                                                                                         |            |                  |                 |
|                                                                                                                                                                                                                                                                         | 2,5        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                       |            |                  |                 |
| Skript<br>C. Lüders, Mobilfunksysteme, Vogel-Verlag 2001<br>J. Schiller, Mobilkommunikation, Addison-Wesley 2000<br>N. Geng, W. Wiesbeck, Planungsmethoden für die Mobilkommunikation, Springer-Verlag 1998<br>A. Molisch, Wireless Communications, Addison-Wesley 2005 |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                    |                                                                                   |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                              | Speech Communication                                                              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                             | 2424500                                                                           | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                          |                                                                                   | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                 | only in the winter term                                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                    | 1                                                                                 | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                              | 4 / 5,0                                                                           | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                       | 150                                                                               |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                               | 56                                                                                | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                            |                                                                                   |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                       | oral exam (30 min) or written exam (90 min) (according to number of participants) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                 | Colloquium or laboratory protocol as proof of performance                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                           |                                                                                   |                   |                                                          |
| <ul style="list-style-type: none"><li>• Speech production</li><li>• Speech perception</li><li>• Linear prediction and speech modelling</li><li>• Speech coding</li><li>• Noise reduction</li><li>• Acoustic echo compensation</li></ul>                                                                            |                                                                                   |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                            |                                                                                   |                   |                                                          |
| After completing this module, students are capable of digital speech signal processing and can apply acquired knowledge of speech production and speech perception as well as algorithms and methods of speech enhancement, speech coding, speech transmission in mobile communication systems, and Voice over IP. |                                                                                   |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                         |                                                                                   |                   |                                                          |
| <ul style="list-style-type: none"><li>- Copies of lecture slides</li><li>- P.Vary u. R.Martin: Digital Speech Transmission, Wiley 2006</li></ul>                                                                                                                                                                   |                                                                                   |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                             |                                                                                   |                   |                                                          |
| This module of the Master's programme is also suited for Bachelor students.<br>Basic knowledge of digital signal processing, e.g., acquired through the module Fundamentals of Digital Signal Processing, facilitate comprehension of this lecture. Basic knowledge of probability calculus is also helpful.       |                                                                                   |                   |                                                          |





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|-----------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                  |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                  |            |                  |                 |
|                                                                                         |            |                  |                 |
| <b>Compulsory attendance</b>                                                            |            |                  |                 |
|                                                                                         |            |                  |                 |
| <b>Name of the course</b>                                                               | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                         | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                       |            |                  |                 |
| Kopien der Vorlesungsfolien P.Vary u. R.Martin: Digital Speech Transmission, Wiley 2006 |            |                  |                 |
|                                                                                         | 2,0        | Laboratory       | german          |
| <b>Literature</b>                                                                       |            |                  |                 |
| siehe Vorlesung                                                                         |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                  |                   |                                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-------------------|--------------------------------------------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Microwave and Wireless Metrology |                   |                                                                                                  |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2424530                          | Module version    |                                                                                                  |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                  | Language          | german                                                                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the winter term          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik                                         |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze<br>Institut für Nachrichtentechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 4 / 5,0                          | Module owner      | Prof. Dr. Thomas Kürner                                                                          |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                              |                   |                                                                                                  |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 56                               | Self studying (h) | 94                                                                                               |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                  |                   |                                                                                                  |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | oral exam (30 min)               |                   |                                                                                                  |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                  |                   |                                                                                                  |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                  |                   |                                                                                                  |
| <ul style="list-style-type: none"><li>- Introduction to metrology</li><li>- Fundamentals of high-frequency technology</li><li>- Measurements in the time domain</li><li>- Spectrum analysis</li><li>- Vector network analysis</li><li>- Antenna measurement technology</li><li>- Channel measurements</li><li>- Protocol measurement technology</li></ul>                                                                                                                                                                                                                  |                                  |                   |                                                                                                  |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                  |                   |                                                                                                  |
| The lecture deals with the basics of modern communication measurement technology. Students will learn about the measurement of signals and transmission characteristics in the time and frequency domain, antenna measurement technology, protocol measurement technology and channel measurement, which are essential for understanding and using state-of-the-art measuring devices, for example in the field of mobile communications. After completing the module, students will be able to use current measurement systems in research and development independently. |                                  |                   |                                                                                                  |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                  |                   |                                                                                                  |
| <ul style="list-style-type: none"><li>- Slides</li><li>- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde &amp; Schwarz, 2004</li><li>- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde &amp; Schwarz, 2007</li><li>- A.Molisch: Wireless Communications, Wiley, 2005</li></ul>                                                                                                                                                                                                                                                                              |                                  |                   |                                                                                                  |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                  |                   |                                                                                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                  |                   |                                                                                                  |



|                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                            | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Foliensammlung</li> <li>- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde &amp; Schwarz, 2004</li> <li>- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde &amp; Schwarz, 2007</li> <li>- A.Molisch: Wireless Communications, Wiley, 2005</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                            | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Foliensammlung</li> <li>- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde &amp; Schwarz, 2004</li> <li>- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde &amp; Schwarz, 2007</li> <li>- A.Molisch: Wireless Communications, Wiley, 2005</li> </ul> |            |                  |                 |

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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Advanced Seminar "Machine Learning" |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2424600                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                     | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                   | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2 / 5,0                             | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 28                                  | Self studying (h) | 122                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                     |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Written paper                       |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                     |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                     |                   |                                                          |
| Changing current research topics in the field of machine learning.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                     |                   |                                                          |
| After completing the module, students will possess advanced skills in writing a scientific paper. In the course of the advanced seminar, current research topics from the area of machine learning are discussed, deepened, and scientifically prepared. The participants will read scientific publications, present them and discuss them jointly. The structure of a scientific conference publication will be covered as well as strategies for the writing of the standard sections of a paper.<br>This course has a discursive character, therefore regular attendance of the participants is required. |                                     |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                     |                   |                                                          |
| Literature will be handed out in the seminar                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                     |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                     |                   |                                                          |
| Basic knowledge of the topics "pattern recognition"/"machine learning" is expected, especially in the field of neural networks and support vector machines.                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                     |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

|                                       |     |         |        |
|---------------------------------------|-----|---------|--------|
|                                       | 2,0 | Lecture | german |
| <b>Literature</b>                     |     |         |        |
| Literatur wird im Seminar ausgegeben. |     |         |        |
|                                       | 0,0 | Project | german |
| <b>Literature</b>                     |     |         |        |
| Literatur wird im Seminar ausgegeben. |     |         |        |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Network Information Theory                  |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2424650                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                           | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 6,0                                     | Module owner      | Dr. Christian Deppe                                      |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 180                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                                          | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>• Review point-to-point channel capacity and coding theorem</li><li>• Strong typical sequences and their properties</li><li>• Multiple-Access Channel: Capacity region compared to TDMA/FDMA/SDMA/NOMA</li><li>• #Broadcast Channel: degraded BC capacity region, non-degraded BC achievable rate region and converse</li><li>• Interference Channel: very strong, strong, weak interference capacity region, medium interference achievable rate region and converse</li><li>• #Relay Channel: achievable schemes amplify-and-forward, decode-and-forward, compress-and-forward, estimate-and-forward</li><li>• #Generalization and application of elements to complex networks</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| After completing the lecture, the students will know the building blocks of complex communications networks, i.e., the multiple-access channel, the broadcast channel, the relay channel and the interference channel, their achievable rates and capacity regions including coding and decoding schemes. In addition, the students obtain knowledge to design future wireless and multi-hop as well as ad-hoc networks. They master information-theoretic and mathematical tools to prove coding theorems. They know the state of the art as well as open problems in network information theory.                                                                                                                               |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| #A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011.<br>D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007.<br>T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006.<br>S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004.<br>R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.                                                                                                                                                                                                                                        |                                             |                   |                                                          |



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| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Network Information Theory                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011<br>D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007<br>T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006<br>S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004<br>R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008        |            |                  |                 |
| Network Information Theory                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| - A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011<br>- D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007<br>- T.M. Cover and J.A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006<br>- S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004<br>- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008 |            |                  |                 |

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| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Spoken Language Processing                                                            |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2424680                                                                               | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                       | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the winter term                                                               | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                                                     | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 4 / 5,0                                                                               | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                                                                   |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 56                                                                                    | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                       |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Oral exam 30 minutes or written exam 90 minutes (depending on number of participants) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                       |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                       |                   |                                                          |
| <ul style="list-style-type: none"><li>- Basics of speech production and perception</li><li>- Feature extraction</li><li>- Hidden Markov models</li><li>- Acoustic models and language models</li><li>- Automatic speech recognition</li><li>- Spoken language systems</li></ul>                                                                                                                                                                                                                                                                                                                                                                           |                                                                                       |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                       |                   |                                                          |
| After successful completion of the module, students will be able to classify time series (e.g., speech signals) using hidden Markov modeling. The students acquire all the necessary knowledge to suitably select, design, and evaluate methods and algorithms for automatic speech recognition to solve problems in practice.                                                                                                                                                                                                                                                                                                                            |                                                                                       |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                   |                                                          |
| <ul style="list-style-type: none"><li>- Lecture slides</li><li>- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001</li><li>- B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008</li><li>- A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004</li><li>- E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995</li><li>- G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003</li><li>- L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993</li><li>- K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990</li></ul> |                                                                                       |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                       |                   |                                                          |
| This module from the master's program is also suitable for bachelor students. Basic knowledge of digital signal processing, as e.g. acquired in the module #digital signal processing#, facilitates the understanding of this lecture.                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                       |                   |                                                          |





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| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <ul style="list-style-type: none"> <li>- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001</li> <li>- B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008</li> <li>- A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004</li> <li>- E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995</li> <li>- G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003</li> <li>- L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993</li> <li>- K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2,0        | Seminar          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <ul style="list-style-type: none"> <li>- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001</li> <li>- B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008</li> <li>- A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004</li> <li>- E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995</li> <li>- G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003</li> <li>- L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993</li> <li>- K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Pattern Recognition                       |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2424690                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | every term                                | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1                                         | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 4 / 5,0                                   | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 150                                       |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 56                                        | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                           |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Oral exam 30 min. or written exam 90 min. |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                           |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                           |                   |                                                          |
| <ul style="list-style-type: none"><li>- Bayesian decision rule</li><li>- Quality metrics in pattern recognition</li><li>- Supervised learning with parametric distributions</li><li>- Supervised learning with non-parametric distributions, classification</li><li>- Linear discriminant functions, single-layer perceptron</li><li>- Support vector machines (SVMs)</li><li>- Multi-layer perceptron, neural networks (NNs)</li><li>- Deep learning</li><li>- Unsupervised learning, clustering methods</li></ul> <p>Note: For pattern recognition using hidden Markov models (HMMs), a separate more in-depth module, Spoken Language Processing (ET-NT-68), is offered in the summer semester.</p> |                                           |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                           |                   |                                                          |
| Upon completion of this module, students gain fundamental knowledge about methods and algorithms for classification of data. They are capable to select the appropriate means for real-world problems, to design a solution and to evaluate it.                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                           |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                           |                   |                                                          |
| <ul style="list-style-type: none"><li>- R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001</li><li>- C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                           |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                           |                   |                                                          |
| Basic knowledge of statistics, such as acquired in the module "Probability Theory and Statistics", facilitates the understanding of the lecture.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                           |                   |                                                          |



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| <b>Related courses</b>                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                            | 2,0        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001</li> <li>- C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006</li> </ul>                             |            |                  |                 |
|                                                                                                                                                                                                                                            | 2,0        | Seminar          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Vorlesungsfolien</li> <li>- R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001</li> <li>- C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Physical Layer Security                                                       |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2424710                                                                       | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                               | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the summer term                                                       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                                             | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                                                       | Module owner      | Prof. Dr. Eduard Jorswieck                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                                                           |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                                                                            | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                               |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Written exam (120) or oral exam (30 min), according to number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                               |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                               |                   |                                                          |
| <div>- Direct data transmission by PhySec: It covers multi-user communications with an additional secrecy constraint. For example, wiretap channels, broadcast channels with confidential messages, etc., and we will analyze the secrecy capacity/capacity region of these channels.</div> <div>- Key generation by PHYSEC: It covers the secret key generation with the source model and the channel model. In the former case, the legitimate users will observe a common source of randomness and try to agree on a secret key, which is unknown to a potential eavesdropper. In the latter one, one of the legitimate users transmits a random sequence through the channel to the other users and again they try to agree on a key. Practical sequential key distillation will also be covered.</div> <div>- Authentication: It covers how to identify the legitimate communication partners by channel testing/probing or by the use of the physically unclonable functions.</div> |                                                                               |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                               |                   |                                                          |
| In this course, we aim to show/provide a rigorous way to develop a security system on the physical layer (PhySec), by taking the physical properties of the communication environments into account. After having attained this course, the students are able to answer questions about a system's security with a fundamental knowledge about physical layer security.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                               |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                               |                   |                                                          |
| <div>- Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011.</div> <div>- Yingbin Liang, H. Vincent Poor und Shlomo Shamai (Shitz): Information Theoretic Security, Now publishers, Foundations and Trends in Communications and Information Theory, vol. 5, no. 4-5, 2008..</div> <div>- T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006.</div> <div>- A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011.</div> <div>- R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.</div>                                                                                                                                                                                                                                                                                     |                                                                               |                   |                                                          |



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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <p>Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011</p> <p>Yingbin Liang, H. Vincent Poor und Shlomo Shamai (Shitz): Information Theoretic Security, Now publishers, Foundations and Trends in Communications and Information Theory, vol. 5, no. 4-5, 2008</p> <p>T.M. Cover and J.A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006</p> <p>A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011</p> <p>R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008</p> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <p>Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011</p> <p>Yingbin Liang, H. Vincent Poor und Shlomo Shamai (Shitz): Information Theoretic Security, Now publishers, Foundations and Trends in Communications and Information Theory, vol. 5, no. 4-5, 2008</p> <p>T.M. Cover and J.A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006</p> <p>A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011</p> <p>R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008</p> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Information Theory                          |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2424720                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                           | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3 / 5,0                                     | Module owner      | Prof. Dr. Eduard Jorswieck                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>Basics from probability theory<ul style="list-style-type: none"><li>Event, probability, random variable, random vector, stochastic process, convergence of random series, convergence theorems</li></ul></li><li>Basics from information theory<ul style="list-style-type: none"><li>Measures for discrete random variables: entropy, conditional entropy, relativ entropy, mutual information, conditional mutual information, inequalities</li><li>Measures for continous random variables: differential entropy, conditional differential entropy, relative entropy, mutual information, inequalities</li><li>Measure for random series</li><li>Typical sequences and asymptotic equipartition property</li></ul></li><li>Source and source coding<ul style="list-style-type: none"><li>Definition and properties</li><li>Source coding for discrete memoryless sources (fixed and variable-length)</li><li>Selected source codes: Morse, Huffman, Shannon-Fano-Elias</li></ul></li><li>Data transmission and channel capacity<ul style="list-style-type: none"><li>Discrete memoryless channel: channel coding theorem</li><li>Discrete memoryless channel with state: channel capacities</li><li>Gaussian channel: model and channel coding theorem</li><li>Bandlimited Gaussian channel, vector valued channels</li></ul></li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| The lecture provides an introduction to the fundamentals of Shannon information theory. The goal is that students can derive the main information theoretic results on maximal achievable lossless (source coding) and lossy (rate distortion theory) compression of data and on maximum data rates for reliable data transmission (channel coding). The methods and tools required, e.g., information measures (entropy, mutual information, capacity etc.) and their properties (typical sequences) will be covered as well as practical applicable simple codes (block, turbo and polar codes).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| #R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.<br>R.W. Yeung: A First Course in Information Theory. Springer. 2002.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |

T.M. Cover und J.A. Thomas: Elements of Information Theory, Wiley-Interscience, 2006.  
 R.G. Gallager: Information Theory and Reliable Communication, Wiley, 1968.  
 R.G. Gallager: Principles of Digital Communication, Cambridge University Press, 2008.  
 S. Moser: S. Moser: Information Theory, <https://moser-isi.ethz.ch/scripts.html#it>



| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |     |           |          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----------|----------|
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |     |           |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |           |          |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |     |           |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |           |          |
| Name of the course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | SWS | Eventtype | Language |
| Information Theory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2,0 | Lecture   | english  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     |           |          |
| <ul style="list-style-type: none"> <li>- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008</li> <li>- R.W. Yeung: A First Course in Information Theory, Springer, 2002</li> <li>- T.M. Cover und J.A. Thomas: Elements of Information Theory, Wiley-Interscience, 2006</li> <li>- R.G. Gallager: Information Theory and Reliable Communication, Wiley, 1968</li> <li>- R.G. Gallager: Principles of Digital Communication, Cambridge University Press, 2008</li> <li>- S. Moser: S. Moser: Information Theory, <a href="https://moser-isi.ethz.ch/scripts.html#it">https://moser-isi.ethz.ch/scripts.html#it</a></li> </ul> |     |           |          |
| Information Theory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1,0 | Exercise  | english  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     |           |          |
| <ul style="list-style-type: none"> <li>- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008</li> <li>- R.W. Yeung: A First Course in Information Theory, Springer, 2002</li> <li>- T.M. Cover und J.A. Thomas: Elements of Information Theory, Wiley-Interscience, 2006</li> <li>- R.G. Gallager: Information Theory and Reliable Communication, Wiley, 1968</li> <li>- R.G. Gallager: Principles of Digital Communication, Cambridge University Press, 2008</li> <li>- S. Moser: S. Moser: Information Theory, <a href="https://moser-isi.ethz.ch/scripts.html#it">https://moser-isi.ethz.ch/scripts.html#it</a></li> </ul> |     |           |          |

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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Physical Layer Security 2                    |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2424740                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the winter term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1                                            | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3 / 5,0                                      | Module owner      | Dr. Pin-Hsun Lin                                         |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 42                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                            | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>• Review of information theory and physical layer security</li><li>• Sequential key distillation</li><li>• Privacy: differential privacy, stealth and covert communications, private information retrieval, wireless privacy</li><li>• Fading channels, ergodic and outage capacities, and artificial noise design</li><li>• Finite block length analysis and wiretap code implementations</li><li>• Active attacker</li></ul> |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |                   |                                                          |
| Students will learn how to use more advanced mathematical tools to analyze more complicated issues in physical layer security, continuing the discussion from the lecture Physical Layer Security. More specifically, the sequential key distillation for secret key generation, privacy issues tackled by physical layer schemes, and the more general setting where the eavesdropper is active, are included in this lecture.                                      |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
| Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011.<br>S. Moser: Information Theory, <a href="https://moser-isi.ethz.ch/scripts.html#it">https://moser-isi.ethz.ch/scripts.html#it</a><br>A. El Gamal and Y.-H. Kim, Network Information Theory, Cambridge University Press, 2011.<br>Research papers.                                                                      |                                              |                   |                                                          |

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| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                    | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                              | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011<br>S. Moser: Information Theory, <a href="https://moser-isi.ethz.ch/scripts.html#it">https://moser-isi.ethz.ch/scripts.html#it</a><br>A. El Gamal and Y.-H. Kim, Network Information Theory, Cambridge University Press, 2011<br>Research papers |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                              | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011<br>S. Moser: Information Theory, <a href="https://moser-isi.ethz.ch/scripts.html#it">https://moser-isi.ethz.ch/scripts.html#it</a><br>A. El Gamal and Y.-H. Kim, Network Information Theory, Cambridge University Press, 2011<br>Research papers |            |                  |                 |

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|--------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------|------------------------------|
| Title                                                                                                                          | Multimedia Networking                                                                 |                   |                              |
| Number                                                                                                                         | 4213170                                                                               | Module version    | V2                           |
| Shorttext                                                                                                                      |                                                                                       | Language          |                              |
| Frequency of offer                                                                                                             | only in the winter term                                                               | Teaching unit     | Carl-Friedrich-Gauß-Fakultät |
| Module duration                                                                                                                |                                                                                       | Institution       |                              |
| Hours per Week / ECTS                                                                                                          | 3 / 5,0                                                                               | Module owner      | Prof. Dr. Lars Wolf          |
| Workload (h)                                                                                                                   | 150                                                                                   |                   |                              |
| Class attendance (h)                                                                                                           | 42                                                                                    | Self studying (h) | 108                          |
| Compulsory requirements                                                                                                        |                                                                                       |                   |                              |
| Expected performance/ Type of examination                                                                                      | 1 graded work: Written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam. |                   |                              |
| Course achievement                                                                                                             |                                                                                       |                   |                              |
| Contents                                                                                                                       |                                                                                       |                   |                              |
|                                                                                                                                |                                                                                       |                   |                              |
| Objective qualification                                                                                                        |                                                                                       |                   |                              |
|                                                                                                                                |                                                                                       |                   |                              |
| Literature                                                                                                                     |                                                                                       |                   |                              |
| <div>- R. Steinmetz: Multimedia Technologie. Springer-Verlag</div> <div>- S. Keshav: Computer Networking, Addison Wesley</div> |                                                                                       |                   |                              |
| Siehe auch Aktualisierung auf der Webseite der Lehrveranstaltung                                                               |                                                                                       |                   |                              |

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|---------------------------------|-----|-----------|----------|
| Related courses                 |     |           |          |
| Rules for the choice of courses |     |           |          |
|                                 |     |           |          |
| Compulsory attendance           |     |           |          |
|                                 |     |           |          |
| Name of the course              | SWS | Eventtype | Language |

|                                                                                                                                                                                                                                                                                               |                                                                                       |                   |                                                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------|-------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                         | Computer Networks 2 (MPO 2017)                                                        |                   |                                                 |
| Number                                                                                                                                                                                                                                                                                        | 4213390                                                                               | Module version    | V2                                              |
| Shorttext                                                                                                                                                                                                                                                                                     |                                                                                       | Language          | english german                                  |
| Frequency of offer                                                                                                                                                                                                                                                                            | only in the winter term                                                               | Teaching unit     | Carl-Friedrich-Gauß-Fakultät                    |
| Module duration                                                                                                                                                                                                                                                                               | 1                                                                                     | Institution       | Institut für Betriebssysteme und Rechnerverbund |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                         | 0 / 5,0                                                                               | Module owner      | Prof. Dr. Lars Wolf                             |
| Workload (h)                                                                                                                                                                                                                                                                                  | 150                                                                                   |                   |                                                 |
| Class attendance (h)                                                                                                                                                                                                                                                                          | 56                                                                                    | Self studying (h) | 94                                              |
| Compulsory requirements                                                                                                                                                                                                                                                                       |                                                                                       |                   |                                                 |
| Recommended requirements                                                                                                                                                                                                                                                                      | INF 2230 (Computer Networks) or equivalent knowledge                                  |                   |                                                 |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                  | 1 graded work: Written exam (90 minutes) or oral exam (20 minutes) or Take-Home-Exam. |                   |                                                 |
| Course achievement                                                                                                                                                                                                                                                                            |                                                                                       |                   |                                                 |
| Contents                                                                                                                                                                                                                                                                                      |                                                                                       |                   |                                                 |
| <div>- Internet protocols</div> <div>- IP</div> <div>- TCP</div> <div>- Routing methods</div> <div>- Newer protocols and methods</div>                                                                                                                                                        |                                                                                       |                   |                                                 |
| Objective qualification                                                                                                                                                                                                                                                                       |                                                                                       |                   |                                                 |
| On completion of this module, students will have deepened their knowledge from the course 'Computer Networks 1'. They will be familiar with the processes used on the Internet and the procedures involved.                                                                                   |                                                                                       |                   |                                                 |
| Literature                                                                                                                                                                                                                                                                                    |                                                                                       |                   |                                                 |
| Andrew Tanenbaum, David Wetherall, Nick Feamster, Computer Networks, 6.Ed. 2021, Print-ISBN: 978-1-292-37406-2, E-ISBN: 978-1-292-37401-7<br>James Kurose, Keith Ross. Computer Networking. A Top-Down Approach, 2021, 8th edition, Print-ISBN: 978-1-292-40546-9, E-ISBN: 978-1-292-40551-3. |                                                                                       |                   |                                                 |

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| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                           |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                        | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                  | 4,0        | Lecture/Exercise | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <p>- Andrew S. Tanenbaum; David J. Wetherall: Computer Networks. International Edition. 5th edition. Pearson, 2010. ISBN-10: 0132553171 / ISBN-13: 9780132553179 - James F. Kurose; Keith W. Ross: Computer Networking: A Top-Down Approach. International Edition. 6th edition. Pearson, 2012. ISBN-10: 0273768964 / ISBN-13: 9780273768968</p> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                  | 2,0        | Exercise         | english         |

|                                              |                       |                   |                              |
|----------------------------------------------|-----------------------|-------------------|------------------------------|
| Title                                        | Mobile Communications |                   |                              |
| Number                                       | 4213420               | Module version    |                              |
| Shorttext                                    |                       | Language          | english german               |
| Frequency of offer                           |                       | Teaching unit     | Carl-Friedrich-Gauß-Fakultät |
| Module duration                              |                       | Institution       |                              |
| Hours per Week / ECTS                        | 0 / 5,0               | Module owner      |                              |
| Workload (h)                                 |                       |                   |                              |
| Class attendance (h)                         |                       | Self studying (h) |                              |
| Compulsory requirements                      |                       |                   |                              |
| Expected performance/<br>Type of examination |                       |                   |                              |
| Course achievement                           |                       |                   |                              |
| Contents                                     |                       |                   |                              |
|                                              |                       |                   |                              |
| Objective qualification                      |                       |                   |                              |
|                                              |                       |                   |                              |
| Literature                                   |                       |                   |                              |
|                                              |                       |                   |                              |



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|---------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                        |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                        |            |                  |                 |
|                                                                                                               |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                  |            |                  |                 |
|                                                                                                               |            |                  |                 |
| <b>Name of the course</b>                                                                                     | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Mobile Communications                                                                                         | 4,0        | Lecture/Exercise | english german  |
| <b>Literature</b>                                                                                             |            |                  |                 |
| J. Schiller: Mobilkommunikation - Techniken für das allgegenwärtige Internet, 2. Auflage, Addison-Wesley 2003 |            |                  |                 |
|                                                                                                               | 2,0        | Exercise         | english german  |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                      | Operating Systems                                                                     |                   |                                                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------|-------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                     | 4225040                                                                               | Module version    | V3                                              |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                       | Language          | german                                          |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                         | only in the winter term                                                               | Teaching unit     | Carl-Friedrich-Gauß-Fakultät                    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                                                                     | Institution       | Institut für Betriebssysteme und Rechnerverbund |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                      | 4 / 5,0                                                                               | Module owner      | Rüdiger Kapitza                                 |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                               | 150                                                                                   |                   |                                                 |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                       | 56                                                                                    | Self studying (h) | 94                                              |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                       |                   |                                                 |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                  | 1 graded work: Written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam. |                   |                                                 |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                         | 1 Coursework: 50% of homework assignments must be passed                              |                   |                                                 |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                       |                   |                                                 |
| <ul style="list-style-type: none"><li>- History of operating systems</li><li>- Process management</li><li>- Interprocess communication</li><li>- Memory management</li><li>- Input and output</li><li>- File systems</li></ul>                                                                                                                                                                                             |                                                                                       |                   |                                                 |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                       |                   |                                                 |
| <ul style="list-style-type: none"><li>- At the end of the course, students will have a good overview of the basic concepts of operating systems.</li><li>- In particular, they will have gained an in-depth understanding of processes and memory management.</li><li>- They will be able to identify the principles they have learned in real operating systems and assess the quality of their implementation.</li></ul> |                                                                                       |                   |                                                 |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                       |                   |                                                 |
| <ul style="list-style-type: none"><li>- A. Tanenbaum:Modern Operating Systems, 2nd., Prentice-Hall,2001.</li><li>- W. Stallings: Operating Systems: International Version: Internals and Design Principles, 7th revised edition,Prentice Hall International, 2011.</li><li>- Silberschatz, Galvin, Gane:Operating System Concepts, 8th edition, John Wiley &amp; Sons, 2011</li></ul>                                      |                                                                                       |                   |                                                 |

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|----------------------------------------|------------|-----------------------|-----------------|
| <b>Related courses</b>                 |            |                       |                 |
| <b>Rules for the choice of courses</b> |            |                       |                 |
|                                        |            |                       |                 |
| <b>Compulsory attendance</b>           |            |                       |                 |
|                                        |            |                       |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b>      | <b>Language</b> |
|                                        | 4,0        | Lecture/Exercise      | german          |
|                                        | 1,0        | Exercise              | german          |
|                                        | 1,0        | Exercise, small group | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Low power CMOS data converter circuit design |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2420210                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | irregular                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                            | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                      | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 36                                           | Self studying (h) | 114                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Oral exam (30 min)                           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| <p>Data converters bridge digital virtual space and analog real world in cyber physical system (CPS), and become key building circuit blocks. This lecture deals with the circuit design of CMOS data converters. In particular, circuit techniques related to low-power and high-resolution ADCs, which are important for sensor signal detection in IoT application, will be explained. It is assumed that the students have basic knowledge of CMOS integrated circuit design and signal processing such as Laplace transform and Z transform.</p> <p>General introduction of data converters</p> <p>1. Data converter application areas</p> <p>Sensor interface, Communication (wireless/wireline)</p> <p>2. Basic theory in data conversion</p> <p>Sampling/Quantization, Performance metric (INL/DNL, SNDR, SFDR, ENOB, FoM)</p> <p>3. Architectures and features of data converters</p> <p>2-1. High resolution data converter (SAR, ##, VCO based)</p> <p>2-2. High speed data converter (Flash, Pipeline)</p> <p>Implementation of low-power and high-resolution CMOS integrated ADCs</p> <p>4. Building blocks of ADC</p> <p>Comparator, operational amplifier</p> <p>5. SAR-ADC with charge redistribution.</p> <p>3-1. Power reduction techniques</p> <p>3-2. Resolution enhancement techniques (digital calibration etc.)</p> <p>6. High resolution ## modulator</p> <p>7. Time based (VCO based) ADC</p> <p>8. Hybrid-ADC</p> <p>9. Characterization of data converters</p> |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                              |                   |                                                          |



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| Related courses                 |     |              |          |
|---------------------------------|-----|--------------|----------|
| Rules for the choice of courses |     |              |          |
|                                 |     |              |          |
| Compulsory attendance           |     |              |          |
|                                 |     |              |          |
| Name of the course              | SWS | Eventtype    | Language |
|                                 | 3,0 | Block course | english  |

|                                                                                                                                                                                                                                                                                                 |                                                      |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                           | Computer Architecture 1                              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                          | 2416010                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                       |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                              | only in the winter term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                 | 1                                                    | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                           | 4 / 6,0                                              | Module owner      | Prof. Dr. Selma Saidi                                    |
| Workload (h)                                                                                                                                                                                                                                                                                    | 180                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                            | 56                                                   | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                       | Written exam (120 minutes) or oral exam (30 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                              |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                        |                                                      |                   |                                                          |
| <ul style="list-style-type: none"><li>• Introduction to computer architecture</li><li>• Principles of computer architecture (control, pipelining, memory hierarchy)</li><li>• Microprocessors (RISC, ISC)</li><li>• Quantitative computer design</li><li>• Design of instruction sets</li></ul> |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| Students have basic knowledge of modern computer architectures and an understanding of the function of modern computers. With the knowledge they have acquired, they are able to configure computer systems on a component basis and evaluate their performance.                                |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                      |                                                      |                   |                                                          |
| D. Patterson, J. L. Hennessy, Computer Organization and Design #– The Hardware/Software Interface, Morgan Kaufmann Publishers, ISBN 978-0-12-370606-5 #<br>W. Stallings, Computer Organization & Architecture, 6. Edition, Prentice Hall, ISBN-13: 978-0-13-035119-7 #<br>Lecture notes         |                                                      |                   |                                                          |

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|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 1,0        | Exercise         | german          |
|                                        | 3,0        | Lecture          | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Media Technologies      |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2424160                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                         | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the winter term | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                       | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 6,0                 | Module owner      | Prof. Dr. Eduard Jorswieck                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 180                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                      | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                         |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                         |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                         |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                         |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                         |                   |                                                          |
| <p>Aktuelle Systeme für die Elektronischen Medien:</p> <ul style="list-style-type: none"><li>- H. Zander: Die aktuelle Audiotechnik, Drei-R-Verlag 1987</li><li>- E. Zwicker, R.Feldtkeller: Das Ohr als Nachrichtenempfänger, S. Hirzel Verlag, 2. Aufl., 1967</li><li>- U. Reimers: DVB-Digitale Fernsehtechnik: Datenkompression und Übertragung, Springer Verlag, 3. Auflage, 2008</li><li>- C. Biaesch-Wiebkke: CD-Player und R-Dat-Recorder, Vogelbuch Verlag, 1992</li><li>- R. Mäusl: Fernsehtechnik, Hüthig Buch Verlag Heidelberg, 2. Aufl., 1995</li><li>- T. Lauterbach: Digital Audio Broadcasting, Franzis-Verlag, 1996</li><li>- D. Führer: ADSL, Hüthig Buch Verlag Heidelberg, 2000</li></ul> <p>Elektroakustik:</p> <ul style="list-style-type: none"><li>- Zollner/Zwicker: Elektroakustik, Springer Verlag</li><li>- Kuttruff: Akustik - Eine Einführung, S. Hirzel Verlag Stuttgart Leipzig</li><li>- Cremer/Möser: Technische Akustik, Springer Verlag</li><li>- Ahnert: Beschallungstechnik, S. Hirzel Verlag Stuttgart Leipzig</li></ul> |                         |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                         |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |



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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                       |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                    | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                              | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| H.Zander: Die Digitale Audiotechnik, Drei-R-Verlag 1987<br>E.Zwicker, R.Feldtkeller: Das Ohr als Nachrichtenempfänger, S.Hirzel Verlag, 2.Aufl., 1967<br>U.Reimers: DVB - Digitales Fernsehen: Datenkompression und Übertragung, Springer Verlag, 3.Aufl., 2008<br>T.Coughlin: Digital Storage in Consumer Electronics, Elsevier-Verlag 2008 |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                              | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| Zoller/Zwicker: Elektroakustik, Springer Verlag<br>Kuttruff: Akustik - Eine Einführung, S.Hirzel Verlag Stuttgart Leipzig<br>Cremer/Möser: Technische Akustik, Springer Verlag<br>Ahnert: Beschallungstechnik, S.Hirzel Verlag Stuttgart Leipzig                                                                                             |            |                  |                 |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Applied Quantum Computing: Basics and Devices                                              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2413620                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                            | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the winter term                                                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                                                                          | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3 / 5,0                                                                                    | Module owner      | Prof. Dr. Stefanie Kroker                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                                                                                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                                                                                         | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                            |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (120 min) or oral exam (30 min), alternativ: homework with final presentation |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                            |                   |                                                          |
| <ul style="list-style-type: none"><li>- Basics of Quantum Mechanics</li><li>- From Bit to Qubit</li><li>- Quantum Circuits I</li><li>- Quantum Circuits II</li><li>- Entanglement and Teleportation</li><li>- Algorithms of Quantum Computing</li><li>- Quantum Hardware I</li><li>- Quantum Hardware II</li></ul>                                                                                                                                                                                                                                                                                                                                                              |                                                                                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                            |                   |                                                          |
| <ul style="list-style-type: none"><li>- The students can name the prerequisites for the realization of qubits as well as typical platforms and explain their significance.</li><li>- Students will be able to name the strengths and weaknesses of different hardware platforms in common application scenarios and weigh them against each other.</li><li>- The students can name the essential process steps for the realization of different quantum computer platforms and to explain challenges that may arise in the manufacturing process.</li><li>- Students will be able to use an exemplary platform to explain how selected quantum gates can be realized.</li></ul> |                                                                                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                            |                   |                                                          |
| <p>[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019</p> <p>[2] M. A. Nielsen &amp; I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010</p> <p>[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019</p> <p>[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018</p> <p>[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019</p>                                                                                                                                                                                                                                      |                                                                                            |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Applied Quantum Computing: Basics and Devices                                                                                                                                                                                                                                                                                                                                                                   | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| [1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019<br>[2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010<br>[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019<br>[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018<br>[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019 |            |                  |                 |
| Applied Quantum Computing: Basics and Devices                                                                                                                                                                                                                                                                                                                                                                   | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Quantum Communication Networks              |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2424000030                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1                                           | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 3 / 6,0                                     | Module owner      | Dr. Christian Deppe                                      |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 180                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 42                                          | Self studying (h) | 138                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (60 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>• Introduction to the basic concepts of quantum mechanics and quantum systems</li><li>• Introduction to quantum information theory</li><li>• Protocols for quantum computation and programming</li><li>• Introduction to quantum communication networks</li><li>• Capacity calculations for entanglement-assisted communication</li><li>• Introduction to communication with the help of quantum repeaters</li></ul>                         |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             |                   |                                                          |
| The students <ul style="list-style-type: none"><li>• know the basics of quantum communication networks</li><li>• understand quantum information theory models</li><li>• can calculate rate limits of quantum information-theoretical networks</li><li>• understand simple protocols for quantum communication networks</li><li>• can simulate simple protocols for quantum communication networks</li><li>• can independently develop their own protocols for new models</li></ul> |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| Bassoli, R., Boche, H., Deppe, C., Ferrara, R., Fitzek, F. H., Janssen, G., & Saeedinaeeni, S. (2021). Quantum communication networks (Vol. 23, pp. 1-213). Berlin/Heidelberg, Germany: Springer.<br>Bassoli, R., Boche, H., Deppe, C., Ferrara, R., Fitzek, F. H., Janssen, G., & Saeedinaeeni, S. (2023). <i>Quantenkommunikationsnetze</i> , Berlin/Heidelberg, Germany: Springer (2023).                                                                                       |                                             |                   |                                                          |





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|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Quantum Communication Networks         | 2,0        | Lecture          | english         |
| Quantum Communication Networks         | 1,0        | Exercise         | english         |

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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | VLSI-Lab                                                                                                                                                                                                                                                                                               |                   |                               |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4211490                                                                                                                                                                                                                                                                                                | Module version    |                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                        | Language          |                               |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the summer term                                                                                                                                                                                                                                                                                | Teaching unit     | Carl-Friedrich-Gauß-Fakultät  |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1                                                                                                                                                                                                                                                                                                      | Institution       |                               |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4 / 5,0                                                                                                                                                                                                                                                                                                | Module owner      | Prof. Dr. Guillermo Payá Vayá |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 150                                                                                                                                                                                                                                                                                                    |                   |                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 56                                                                                                                                                                                                                                                                                                     | Self studying (h) | 94                            |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                        |                   |                               |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | The modules “Hardware-Software-Systems” and “Hardware Praktikum” are recommended as preparation for the laboratory. In addition, the modules “VLSI Design” and “Verification, Validation and Testing of ASIC Designs” are recommended to attend in parallel during the realization of this laboratory. |                   |                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                        |                   |                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | non-graded work: successful completion of the given tasks; presentation of 30 minutes                                                                                                                                                                                                                  |                   |                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                        |                   |                               |
| <p>The Chip Design Laboratory is divided into three successive phases. All phases of the laboratory consist of interactive self-study and seminars. The latter provide students with the knowledge necessary to work on the tasks in small groups in self-study. During the independently organized work in the groups on a defined task (self-study), a research associate of the institute checks the progress and gives assistance if necessary. Phase 0: Chip conception and specification The hardware modules to be implemented in phase 1 are designed and specified in small groups during this phase. This phase is based on the target application to be executed on the hardware. The application as well as the hardware modules in form of a microcontroller, peripheral modules and co-processors are selected and all necessary features of these are summarized and documented in this phase. Phase 1: Module implementation and verification At the beginning of phase 1, the students implement individual hardware modules specified in phase 0, i.e., a microcontroller, peripheral modules and co-processors, in small groups using VHDL. The knowledge from previous courses, which is required for VHDL design and testbenches (with System-C), is refreshed and extended in two seminars. Phase 2: Chip design and prototyping After the module development, different groups perform: • functional verification and emulation using a FPGA evaluation board (in-circuit emulation), • performing a complete ASIC synthesis and back-end flow based on a library of standard cells, and • porting a small application onto the system...</p> |                                                                                                                                                                                                                                                                                                        |                   |                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                        |                   |                               |
| <p>The Chip-Design-Lab is a practical laboratory for the design of integrated digital circuits. In this laboratory, students design digital circuits using a RISC-V microcontroller with</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                        |                   |                               |

peripheral modules. During the different phases of the lab, the students design, specify, implement and verify digital circuits with hardware description languages, industrial EDA tools, System-C testbenches and hardware test setups. The qualification goals taught in this laboratory are successful project work in the field of digital circuit design from the specification to the in-circuit test of the designed circuit. The students gain knowledge about project planning, development work and teamwork. At the same time, students acquire specialized knowledge in their own work with used tools and hardware description languages. The goal is the successful and self-developed completion of the project and the exchange of the knowledge gained in teamwork.

#### Literature

- Rabaey, J. M., Chandrakasan, A. P., & Nikoli#, B. (2003). Digital integrated circuits: a design perspective (Vol. 7). Upper Saddle River, NJ: Pearson Education.
- Weste, N. H., & Harris, D. (2015). CMOS VLSI design: a circuits and systems perspective. Pearson Education India.
- Brunvand, E. (2010). Digital VLSI chip design with Cadence and Synopsys CAD tools. Addison-Wesley.
- Ashenden, P. J. (2010). The designer's guide to VHDL. Morgan Kaufmann.
- Ashenden, P. (2008). Digital Design: An Embedded Systems Approach Using VHDL. Morgan Kaufmann.

Further references will be announced in the course.



| Related courses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |            |          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------|----------|
| Rules for the choice of courses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |            |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |            |          |
| Compulsory attendance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |            |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |            |          |
| Name of the course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | SWS | Eventtype  | Language |
| VLSI-Lab                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 4,0 | Internship | english  |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |            |          |
| <ul style="list-style-type: none"> <li>• Rabaey, J. M., Chandrakasan, A. P., &amp; Nikoli#, B. (2003). Digital integrated circuits: a design perspective (Vol. 7). Upper Saddle River, NJ: Pearson Education.</li> <li>• Weste, N. H., &amp; Harris, D. (2015). CMOS VLSI design: a circuits and systems perspective. Pearson Education India.</li> <li>• Brunvand, E. (2010). Digital VLSI chip design with Cadence and Synopsys CAD tools. Addison-Wesley.</li> <li>• Ashenden, P. J. (2010). The designer's guide to VHDL. Morgan Kaufmann.</li> <li>• Ashenden, P. (2008). Digital Design: An Embedded Systems Approach Using VHDL. Morgan Kaufmann.</li> </ul> <p>Further references will be announced in the course.</p> |     |            |          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                  |                   |                               |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4211480                                                                                                          | Module version    | V2                            |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                  | Language          |                               |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the winter term                                                                                          | Teaching unit     | Carl-Friedrich-Gauß-Fakultät  |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 Semester                                                                                                       | Institution       |                               |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4 / 5,0                                                                                                          | Module owner      | Prof. Dr. Guillermo Payá Vayá |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 150                                                                                                              |                   |                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 56                                                                                                               | Self studying (h) | 94                            |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                  |                   |                               |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | The modules “Hardware-Software-Systeme” and “Hardware Praktikum” are recommended as preparation for this course. |                   |                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Graded work (examination): Written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam.                |                   |                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                  |                   |                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                  |                   |                               |
| <ul style="list-style-type: none"><li>- Introduction to VLSI Design</li><li>- Fundamentals of CMOS Transistors</li><li>- Fabrication and Layout of CMOS Integrated Circuits</li><li>- CMOS Circuits (Combinational and Sequential Logic Circuits)</li><li>- Design Methodologies</li><li>- Issues in Chip Design</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                  |                   |                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                  |                   |                               |
| This lecture deals with the design of digital circuits in CMOS technology. The students learn about alternative techniques for the realization of basic circuits as well as their manufacturing and design process. By using practical examples, various forms of implementation of integrated circuits are discussed and current challenges of today's chip development in modern semiconductor technologies are presented. After completing the module, students are able to independently design VLSI chips.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                  |                   |                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                  |                   |                               |
| <ul style="list-style-type: none"><li>- D. Harris, N. Weste: "CMOS VLSI Design.", Pearson Education, Inc (2010).</li><li>- H. Veendrick: "Nanometer CMOS ICs ", Springer, 2007</li><li>- Y. Taur, T. Ning: "Fundamentals of Modern VLSI Devices", Cambridge University Press, 1998</li><li>- J.M. Rabaey, A. P. Chandrakasan, and B. Nikoli#, “Digital Integrated Circuits: a Design Perspective”. Vol. 7. Upper Saddle River, NJ: Pearson Education, 2003.</li><li>- J. Uyemura: "CMOS Logic Circuit Design", Kluwer Academic Publishers, 1999</li><li>- K. Reifschneider: "CAE-gestützte IC-Entwurfsmethoden", Prentice Hall, 1998</li><li>- K. Itoh: "VLSI Memory Chip Design", Springer, 2001</li><li>- D. Jansen: "Handbuch der Electronic Design Automation", Carl Hanser Verlag, 2002</li><li>- R. J. Baker, H. W. Li, D. E. Byce: "CMOS Circuit Design. Layout, and Simulation", IEEE Press 1998</li><li>- R. Hunter, T. Johnson: "VHDL", Springer, 2007</li><li>- D. Perry: "VHDL", McGraw-Hill, 1998</li><li>- P. Ashenden: "The Designers Guide to VHDL", Morgan Kaufmann, 2002</li></ul> |                                                                                                                  |                   |                               |
| Further references will be announced in the course.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                  |                   |                               |



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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| VLSI-Design                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <p>- D. Harris, N. Weste: "CMOS VLSI Design.", Pearson Education, Inc (2010). - H. Veen-<br/>drick: "Nanometer CMOS ICs ", Springer, 2007 - Y. Taur, T. Ning: "Fundamentals of<br/>Modern VLSI Devices", Cambridge University Press, 1998 - J.M. Rabaey, A. P. Chandra-<br/>kasan, and B. Nikoli#, "Digital Integrated Circuits: a Design Perspective". Vol. 7. Upper<br/>Saddle River, NJ: Pearson Education, 2003. - J. Uyemura: "CMOS Logic Circuit Design",<br/>Kluwer Academic Publishers, 1999 - K. Reifschneider: "CAE-gestützte IC-Entwurfsme-<br/>thoden", Prentice Hall, 1998 - K. Itoh: "VLSI Memory Chip Design", Springer, 2001 - D.<br/>Jansen: "Handbuch der Electronic Design Automation", Carl Hanser Verlag, 2002 - R. J.<br/>Baker, H. W. Li, D. E. Byce: "CMOS Circuit Design. Layout, and Simulation", IEEE Press<br/>1998 - R. Hunter, T. Johnson: "VHDL", Springer, 2007 - D. Perry: "VHDL", McGraw-Hill,<br/>1998 - P. Ashenden: "The Designers Guide to VHDL", Morgan Kaufmann, 2002 Further<br/>references will be announced in the course.</p> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2,0        | Exercise         | english         |

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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Post Shannon Theory                                                              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2424000040                                                                       | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                  | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                     | only in the winter term                                                          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1                                                                                | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                  | 3 / 6,0                                                                          | Module owner      | Dr. Christian Deppe                                      |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                           | 180                                                                              |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                   | 42                                                                               | Self studying (h) | 138                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                  |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                              | Written exam (90 min) or oral exam (30 min), according to number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                  |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                  |                   |                                                          |
| <ul style="list-style-type: none"><li>• Introduction to the basic concepts of Post Shannon Theory</li><li>• Introduction to message identification</li><li>• Proof techniques for randomized and deterministic encoding</li><li>• Protocols with resources (feedback, sensing, common randomness)</li><li>• Methods for calculating upper bounds on capacity (resolvability)</li><li>• Coding methods for message identification</li></ul>             |                                                                                  |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                  |                   |                                                          |
| The students <ul style="list-style-type: none"><li>• know the basics of post Shannon theory</li><li>• understand randomized and deterministic message identification</li><li>• can calculate rate limits of Post Shannon models</li><li>• understand simple message identification protocols</li><li>• can create simple coding for message identification themselves</li><li>• can independently develop their own protocols for new models</li></ul> |                                                                                  |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                  |                   |                                                          |
| Ahlswede, Alexander; Althöfer, Ingo; Deppe, Christian; Tamm, Ulrich (Eds.) Identification and Other Probabilistic Models Rudolf Ahlswede's Lectures on Information Theory 6 Springer-Verlag Series: Foundations in Signal Processing, Communications and Networking, Vol. 16 1st Edition, 2021, ISBN: 978-3-030-65070-4                                                                                                                                |                                                                                  |                   |                                                          |

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|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                  |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                               | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Post Shannon Theory                                                                                                                                                                                                                                                                                                     | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| Ahlsvede, Alexander; Althöfer, Ingo; Deppe, Christian; Tamm, Ulrich (Eds.) Identification and Other Probabilistic Models Rudolf Ahlsvede's Lectures on Information Theory 6 Springer-Verlag Series: Foundations in Signal Processing, Communications and Networking, Vol. 16 1st Edition, 2021, ISBN: 978-3-030-65070-4 |            |                  |                 |
| Post Shannon Theory                                                                                                                                                                                                                                                                                                     | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| Ahlsvede, Alexander; Althöfer, Ingo; Deppe, Christian; Tamm, Ulrich (Eds.) Identification and Other Probabilistic Models Rudolf Ahlsvede's Lectures on Information Theory 6 Springer-Verlag Series: Foundations in Signal Processing, Communications and Networking, Vol. 16 1st Edition, 2021, ISBN: 978-3-030-65070-4 |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Hardware Software Codesign                                                                                                                                                               |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2416000010                                                                                                                                                                               | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                          | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the winter term                                                                                                                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                                                                                                                                                                        | Institution       | Institut für Computer Engineering                        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 6,0                                                                                                                                                                                  | Module owner      | Prof. Dr. Selma Saidi                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 180                                                                                                                                                                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                                                                                                                                                                                       | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Basic knowlesge of computer architectures and programming language C                                                                                                                     |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1. Written exam (max 180 min) or oral exam (max 40 min)<br>2. Project work incl. written reports<br><br>The overall grade is the arithmetic average of the grades of components 1 and 2. |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                          |                   |                                                          |
| 1. Design of mixed Hardware/Software solutions for embedded systems<br>2. Understanding of design components<br>3. Understanding of system-level design paradigms<br>4. HW/SW partitioning<br>5. Optimization methods<br>6. Performance analysis measures<br>7. Evaluation methods<br>8. Modelling and Performance analysis of safety-critical and real-time embedded systems.                                                                                                                                                                                                   |                                                                                                                                                                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                          |                   |                                                          |
| The students know the basic design of complex electronic systems at high level of abstractions. This includes the optimized partitioning, scheduling and evaluation of mixed hardware and software design solutions dedicated to embedded systems. The students understand about advanced related topics in HW/SW codesign and performance analysis for safety critical and real-time embedded systems. Starting from simple system specification the students can use tools for partitioning, optimization and performance analysis to synthesize the hardware/software system. |                                                                                                                                                                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                          |                   |                                                          |
| [1] „Specification and Design of Embedded Systems“, D. Gajski, Prentice Hall 1994, ISBN 0-13-150731-1<br>[2] „Digitale Hardware/Software Systeme – Synthese und Optimierung“, J. Teich, Springer Verlag 1997, ISBN 3-540-62433-3                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                          |                   |                                                          |

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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                           |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                           |            |                  |                 |
|                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                        | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Hardware Software Codesign                                                                                                                                                                                                       | 3,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                |            |                  |                 |
| [1] „Specification and Design of Embedded Systems“, D. Gajski, Prentice Hall 1994, ISBN 0-13-150731-1<br>[2] „Digitale Hardware/Software Systeme – Synthese und Optimierung“, J. Teich, Springer Verlag 1997, ISBN 3-540-62433-3 |            |                  |                 |
| Hardware Software Codesign                                                                                                                                                                                                       | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                |            |                  |                 |
| [1] „Specification and Design of Embedded Systems“, D. Gajski, Prentice Hall 1994, ISBN 0-13-150731-1<br>[2] „Digitale Hardware/Software Systeme – Synthese und Optimierung“, J. Teich, Springer Verlag 1997, ISBN 3-540-62433-3 |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                              |                   |                                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Micro- and Precision Assembly                                                                |                   |                                                      |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2522910                                                                                      | Module version    |                                                      |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                              | Language          | german                                               |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term                                                                      | Teaching unit     | Fakultät für Maschinenbau                            |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                                                                            | Institution       | Institut für Werkzeugmaschinen und Fertigungstechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 3 / 5,0                                                                                      | Module owner      | Prof. Dr. Klaus Dröder                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                                                                                          |                   |                                                      |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 42                                                                                           | Self studying (h) | 108                                                  |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | none                                                                                         |                   |                                                      |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Necessary prior knowledge: none # Recommended prior knowledge: basic technical understanding |                   |                                                      |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1 Examination element: written exam (120 min) or oral exam (30 min)                          |                   |                                                      |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                              |                   |                                                      |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                              |                   |                                                      |
| <ul style="list-style-type: none"><li>• Production technologies of micro and precision assembly #</li><li>• Typical components and assemblies used in micro and precision assembly and their development roadmaps # Established joining technologies in micro and precision assembly #</li><li>• Structured analysis of micro and precision assembly tasks #</li><li>• Typical kinematic structures of handling systems #</li><li>• Machine capability analysis for quantitative evaluation of the application-specific performance of assembly systems</li><li>• Kinematic error analysis for methodical analysis of the kinematically caused influences of structural and drive errors on the positioning accuracy of automated systems #</li><li>• Approaches to further increase the accuracy of assembly systems # Analysis techniques and methods for quality assurance</li></ul>                                                                                                                                                                                                                                                                                          |                                                                                              |                   |                                                      |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                              |                   |                                                      |
| Students... # <ul style="list-style-type: none"><li>• are able to name and explain production processes and their elements in precision and micro production #</li><li>• are able to name and explain basic aspects of precision assembly, production lines, robot structures, micro assembly systems, process development and new trends (such as desktop factories) #</li><li>• are able to recognize and distinguish individual components of complex micro and precision assemblies and select suitable assembly technologies #</li><li>• are familiar with the technical equipment components of complex assembly systems and can assess system configurations for specific tasks know basic design principles of accuracy-critical assembly processes and can apply them #</li><li>• are able to assess and differentiate between various kinematic structures and perform simple calculations with regard to their accuracy #</li><li>• are able to find approaches to increase the accuracy of processes and systems, to analyze micro and precision assembly tasks as well as to show approaches for the development of these assembly tasks prototypically #</li></ul> |                                                                                              |                   |                                                      |

- are familiar with analysis techniques and methods for quality assurance of micro and precision assembly processes

#### Literature

- Wrege, Jan: Vorlesungsfolien Mikro- und Präzisionsmontage

Nicht Prüfungsrelevante, ergänzende Literatur: #

- EN ISO 9283 #Industrieroboter: Leistungskenngrößen und zugehörige Prüfmethode# #
- Fatikow, S.: Mikroroboter und Mikromontage, B. G. Teubner, 2000 #
- Knoll, A.; Christaller, T.: Robotik. Fischer, Frankfurt, November 2003

Die Studierenden werden über weitere Literatur im Rahmen der Vorlesung und Übung informiert.



#### Related courses

##### Rules for the choice of courses

##### Compulsory attendance

| Name of the course | SWS | Eventtype | Language |
|--------------------|-----|-----------|----------|
|                    | 2,0 | Lecture   | german   |
|                    | 1,0 | Exercise  | german   |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Advanced Topics in Network Engineering |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2416780                                | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                        | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | only in the winter term                | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1                                      | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 3 / 5,0                                | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 150                                    |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 42                                     | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                        |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                       | oral exam (30 min)                     |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                        |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                        |                   |                                                          |
| <ul style="list-style-type: none"><li>• Cross Layer Design</li><li>• All-IP networks</li><li>• Integration of IP and Optical</li><li>• Inter-domain Routing</li><li>• Networks for Data Centers, Storage and Grid Computing</li><li>• Economics, Standards and Regulations in Telecommunications</li><li>• Applications of Networking in Energy, Automation and Health Care</li><li>• Research Literature, Papers and Surveys</li></ul>                                            |                                        |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                        |                   |                                                          |
| Upon completion of this module, students will have in-depth knowledge of the state of the art and future research topics in the field of architectures and protocols in communication networks. The foundations in this class will help students to better understanding the interaction of complex multi-layered and heterogeneous network architectures and to learning how to engineer the network.                                                                             |                                        |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                        |                   |                                                          |
| G. Camarillo, M. García-Martín, The 3G IP Multimedia Subsystem (IMS): Merging the Internet and the Cellular Worlds, John Wiley & Sons, 2004, ISBN: 978-0-470-87156-0<br>F. Travostino, J. Membretti, G. Karmous-Edwards (Eds.), Grid Networks: Enabling Grids with Advanced Communication Technology, John Wiley & Sons, 2006, ISBN: 978-0-470-01748-7<br>K. M. Sivalingam and T. Znati (Eds), Wireless Sensor Networks, Kluwer Academic Publishers, 2005, ISBN: 978-1-4020-7883-5 |                                        |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                        |                   |                                                          |
| Knowledge of the content of the module Communication Networks are required.                                                                                                                                                                                                                                                                                                                                                                                                        |                                        |                   |                                                          |



|                                                                    |            |                  |                 |
|--------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                             |            |                  |                 |
| <b>Rules for the choice of courses</b>                             |            |                  |                 |
|                                                                    |            |                  |                 |
| <b>Compulsory attendance</b>                                       |            |                  |                 |
|                                                                    |            |                  |                 |
| <b>Name of the course</b>                                          | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                    | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                  |            |                  |                 |
| Include latest research papers, tutorials and industrial standards |            |                  |                 |
|                                                                    | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                  |            |                  |                 |
| Include latest research papers, tutorials and industrial standards |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                              |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Emerging Memory Technologies |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2420000000                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the winter term      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                            | Institution       | Institut für Neuromorphic Computing                      |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3 / 5,0                      | Module owner      | Prof. Dr. Thomas Kämpfe                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Oral exam (30 min)           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                              |                   |                                                          |
| <p>In this course, students will learn about the leading contenders for post-silicon storage-class and main memory technologies. Decades of research have yielded several efficient memory device working principles, including phase-change of the structure (PCM), materials conversion (OxRAM), ion diffusion (CBRAM), magnetic properties (STT-MRAM, MTJ), and ferroelectricity (FRAM, FeFET). Currently, these memory technologies are transitioning from research to industry, and are predicted to have at least niche applications in the ever-growing hardware market. Some technologies, such as PCM, may even eventually surpass silicon-based flash memory, providing better performance and unique features.</p> <p>Students will have the opportunity to compare emerging memory technologies with state-of-the-art SSD Flash, DRAM, and SRAM, as well as evaluate their potential. Through critical thinking discussions, students will acquire important skills for assessing the strengths and limitations of these emerging technologies.</p> |                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                              |                   |                                                          |
| <p>After successfully completing the module, students will understand the biological principles of neural information processing and their differences to the von Neumann architecture. They know the basic methods for hardware implementation of neuromorphic systems. They will also be able to design simple neuromorphic algorithms for specific applications and analyze their performance. Finally, they will be able to evaluate the strengths, weaknesses and current developments of neuromorphic systems and assess their potential for various application areas.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                              |                   |                                                          |
| <ul style="list-style-type: none"><li>• Neuromorphic Computing for Computer Scientists</li><li>• Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601</li><li>• Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. <a href="https://www.nature.com/articles/s41928-023-01053-4">https://www.nature.com/articles/s41928-023-01053-4</a></li><li>• C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 <a href="https://www.nature.com/articles/s43588-021-00184-y">https://www.nature.com/articles/s43588-021-00184-y</a></li></ul>                                                                                                                                                                                                                                                                                                                              |                              |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Emerging Memory Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <ul style="list-style-type: none"> <li>• T. Schenk et al., Memory technology – a primer for material scientists. Reports on Progress in Physics, 2020, 83, 086501. <a href="https://doi.org/10.1088/1361-6633/ab8f86">https://doi.org/10.1088/1361-6633/ab8f86</a></li> <li>• W. Zhang et al., Designing crystallization in phase- change materials for universal memory and neuro-inspired computing. Nature Reviews Materials, 2019, 4, 150. <a href="https://doi.org/10.1038/s41578-018-0076-x">https://doi.org/10.1038/s41578-018-0076-x</a></li> <li>• D. Lencer et al., Design Rules for Phase-Change Materials in Data Storage Applications. Advanced Materials, 2011, 23 (18), 2030. <a href="https://doi.org/10.1002/adma.201004255">https://doi.org/10.1002/adma.201004255</a></li> <li>• S. W. Fong et al., Phase-Change Memory – Towards a Storage-Class Memory. IEEE Transactions on Electron Devices, 2017, 64 (11), 4374. <a href="https://doi.org/10.1109/TED.2017.2746342">https://doi.org/10.1109/TED.2017.2746342</a></li> <li>• S. Yuasa et al., Materials for spin-transfer-torque magnetoresistive random-access memory. MRS Bulletin, 2018, 43, 352. <a href="https://doi.org/10.1557/mrs.2018.93">https://doi.org/10.1557/mrs.2018.93</a></li> <li>• S. Ikegawa et al., Magnetoresistive Random Access Memory: Present and Future. IEEE Transactions on Electron Devices, 2020, 67 (4), 1407. <a href="https://doi.org/10.1109/TED.2020.2965403">https://doi.org/10.1109/TED.2020.2965403</a></li> <li>• H.-S. Philip Wong et al., Metal-Oxide RRAM. Proceedings of the IEEE, 2012, 100 (6), 1951. <a href="https://doi.org/10.1109/JPROC.2012.2190369">https://doi.org/10.1109/JPROC.2012.2190369</a></li> <li>• M. N. Kozicki et al., Conductive bridging random access memory – materials, devices and applications. Semiconductor Science and Technology, 2016, 31 (11), 113001. <a href="https://doi.org/10.1088/0268-1242/31/11/113001">https://doi.org/10.1088/0268-1242/31/11/113001</a></li> </ul> |            |                  |                 |
| Emerging Memory Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <ul style="list-style-type: none"> <li>• T. Schenk et al., Memory technology – a primer for material scientists. Reports on Progress in Physics, 2020, 83, 086501. <a href="https://doi.org/10.1088/1361-6633/ab8f86">https://doi.org/10.1088/1361-6633/ab8f86</a></li> <li>• W. Zhang et al., Designing crystallization in phase- change materials for universal memory and neuro-inspired computing. Nature Reviews Materials, 2019, 4, 150. <a href="https://doi.org/10.1038/s41578-018-0076-x">https://doi.org/10.1038/s41578-018-0076-x</a></li> <li>• D. Lencer et al., Design Rules for Phase-Change Materials in Data Storage Applications. Advanced Materials, 2011, 23 (18), 2030. <a href="https://doi.org/10.1002/adma.201004255">https://doi.org/10.1002/adma.201004255</a></li> <li>• S. W. Fong et al., Phase-Change Memory – Towards a Storage-Class Memory. IEEE Transactions on Electron Devices, 2017, 64 (11), 4374. <a href="https://doi.org/10.1109/TED.2017.2746342">https://doi.org/10.1109/TED.2017.2746342</a></li> <li>• S. Yuasa et al., Materials for spin-transfer-torque magnetoresistive random-access memory. MRS Bulletin, 2018, 43, 352. <a href="https://doi.org/10.1557/mrs.2018.93">https://doi.org/10.1557/mrs.2018.93</a></li> <li>• S. Ikegawa et al., Magnetoresistive Random Access Memory: Present and Future. IEEE Transactions on Electron Devices, 2020, 67 (4), 1407. <a href="https://doi.org/10.1109/TED.2020.2965403">https://doi.org/10.1109/TED.2020.2965403</a></li> <li>• H.-S. Philip Wong et al., Metal-Oxide RRAM. Proceedings of the IEEE, 2012, 100 (6), 1951. <a href="https://doi.org/10.1109/JPROC.2012.2190369">https://doi.org/10.1109/JPROC.2012.2190369</a></li> <li>• M. N. Kozicki et al., Conductive bridging random access memory – materials, devices and applications. Semiconductor Science and Technology, 2016, 31 (11), 113001. <a href="https://doi.org/10.1088/0268-1242/31/11/113001">https://doi.org/10.1088/0268-1242/31/11/113001</a></li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Neuromorphic Computing & Engineering |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2420000010                           | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                      | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                    | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 3 / 5,0                              | Module owner      | Prof. Dr. Thomas Kämpfe                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 42                                   | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                      |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Oral exam (30 min)                   |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                      |                   |                                                          |
| <p>Neuromorphic computing is an approach which is inspired by the structure and function of human brains. Neuromorphic computers are based on Silicon devices which use physical artificial neurons and synapses to apply computations. In recent times, the term neuromorphic has been used to describe analog, digital, mixed-mode analog/digital VLSI, and software systems that implement models of neural systems. The implementation of neuromorphic computing on the hardware level can be realized by oxide-based resistive or ferro-electric memristors.</p> <p>The lecture presents the principles of biological computation and their implementation in hardware. Basic building blocks of neuromorphic technology are presented. The implications for the development of novel information processing technologies are outlined.</p> |                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                      |                   |                                                          |
| After successfully completing the module, students will have understand the principles of biological computation. They will know how to implement them in hardware. They will have basic skills in applying neuromorphic engineering.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                      |                   |                                                          |
| <ul style="list-style-type: none"><li>• Neuromorphic Computing for Computer Scientists</li><li>• Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601</li><li>• Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. <a href="https://www.nature.com/articles/s41928-023-01053-4">https://www.nature.com/articles/s41928-023-01053-4</a></li><li>• C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 <a href="https://www.nature.com/articles/s43588-021-00184-y">https://www.nature.com/articles/s43588-021-00184-y</a></li></ul>                                                                                                               |                                      |                   |                                                          |





| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |           |          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----------|----------|
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |           |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |     |           |          |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |     |           |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |     |           |          |
| Name of the course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | SWS | Eventtype | Language |
| Neuromorphic Computing & Engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2,0 | Lecture   | english  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |     |           |          |
| <ul style="list-style-type: none"> <li>• Neuromorphic Computing for Computer Scientists</li> <li>• Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601</li> <li>• Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. <a href="https://www.nature.com/articles/s41928-023-01053-4">https://www.nature.com/articles/s41928-023-01053-4</a></li> <li>• C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 <a href="https://www.nature.com/articles/s43588-021-00184-y">https://www.nature.com/articles/s43588-021-00184-y</a></li> </ul> |     |           |          |
| Neuromorphic Computing & Engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1,0 | Exercise  | english  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |     |           |          |
| <ul style="list-style-type: none"> <li>• Neuromorphic Computing for Computer Scientists</li> <li>• Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601</li> <li>• Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. <a href="https://www.nature.com/articles/s41928-023-01053-4">https://www.nature.com/articles/s41928-023-01053-4</a></li> <li>• C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 <a href="https://www.nature.com/articles/s43588-021-00184-y">https://www.nature.com/articles/s43588-021-00184-y</a></li> </ul> |     |           |          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Phase-Locked Loops and Frequency Synthesis  |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2420000020                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1                                           | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 3 / 5,0                                     | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Basic knowledge in analogue circuits        |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | oral exam (30 min) or written exam (60 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>- System overview</li><li>- Jitter and phase noise</li><li>- Basic PLL architectures</li><li>- Analog integer PLL</li><li>- Digital integer PLL</li><li>- Fractional PLL</li><li>- Clock data recovery</li><li>- Delay locked loop</li><li>- Numerically controlled oscillator</li><li>- Software PLL</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| Upon completion of the module, students will have a comprehensive understanding of the fundamentals and advanced concepts of phase-locked loops (PLLs) and frequency synthesis. They will be familiar with the systematic architecture of various PLL types, including analog and digital integer PLLs as well as fractional PLLs. Students will understand the causes and effects of jitter and phase noise, and will be able to evaluate and minimize them. They will be acquainted with specialized circuits such as Costas loops, delay locked loops (DLL), numerically controlled oscillators (NCOs), and software-based PLL implementations. The knowledge they acquire enables students to independently research related topics and apply theory to practice. This allows them to analyze and solve practical problems independently. |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                             |                   |                                                          |
| Best, Roland E., Phase-Locked Loops: Design, Simulation, and Applications. 6. Auflage, McGraw-Hill Education, 2007<br>Behzad Razavi "Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level", Cambridge University Press, 2020                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |



|                                                                                                                               |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                        |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                        |            |                  |                 |
|                                                                                                                               |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                  |            |                  |                 |
|                                                                                                                               |            |                  |                 |
| <b>Name of the course</b>                                                                                                     | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Phase-Locked Loops and Frequency Synthesis                                                                                    | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                             |            |                  |                 |
| Best, Roland E., Phase-Locked Loops: Design, Simulation, and Applications. 6. Auflage, McGraw-Hill Education, 2007.           |            |                  |                 |
| Behzad Razavi "Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level", Cambridge University Press, 2020 |            |                  |                 |
| Phase-Locked Loops and Frequency Synthesis                                                                                    | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                             |            |                  |                 |
| Best, Roland E., Phase-Locked Loops: Design, Simulation, and Applications. 6. Auflage, McGraw-Hill Education, 2007.           |            |                  |                 |
| Behzad Razavi "Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level", Cambridge University Press, 2020 |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Verification, Validation and Testing of ASIC Designs |                   |                                      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|--------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 4211500                                              | Module version    |                                      |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                      | Language          | english                              |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the summer term                              | Teaching unit     |                                      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                                    | Institution       | Institut für Theoretische Informatik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                              | Module owner      | Prof. Dr. Guillermo Payá Vayá        |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                                  |                   |                                      |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                                                   | Self studying (h) | 94                                   |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                      |                   |                                      |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | graded work (examination): oral exam (30 minutes)    |                   |                                      |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                      |                   |                                      |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                      |
| 1. Einführung in Verifikation, Validierung und Testing 2. Pre-Silicon Verifikation 2.1 Einführung in ASIC Design Verifikation 2.2 Herangehensweisen zu funktionaler Verifikation 2.3 Verifikationswerkzeuge 2.4 Verifikation Strategien 2.5 Design for Reuse 3. Post-Silicon Validierung 3.1 Einführung in ASIC Validierung 3.2 Traditionelle Post-Silicon Validierung (in der Industrie) 3.3 Reversi Test Generation System 4. Run-Time Verifikation 4.1 Motivation für Laufzeit-Verifikation 4.2 Klassifikation von Laufzeit-Verifikationslösungen 4.3 Dynamische Implementierung von Verifikations- Architekturen 4.4 Run-time Verifikation von einfachen Cores 4.5 Hardware Patching Herangehensweisen 5. Testing 5.1 Einführung zu VLSI Testing 5.2 Design for Testability 5.3 Test Generation |                                                      |                   |                                      |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                      |                   |                                      |
| Die Studierenden lernen Techniken zur Verifikation, Validierung und dem Testen von ASIC-Designs kennen. Auf Basis von praktischen Beispielen und aktuellen Entwicklungswerkzeugen werden die Studierenden an Herausforderungen der heutigen Chipentwicklung und dem Testen herangeführt.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                      |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                      |                   |                                      |
| - Wagner and Bertacco (2011): "Post-Silicon and Runtime Verification for Modern Processors" - Wang, Stroud, and Toubia (2008): "System-on-Chip Test Architectures: Nanometer Design for Testability" - Mishra and Dutt (2005): "Functional Verification of Programmable Embedded Architectures: A Top-Down Approach" - Haque, Khan, and Michelson (2001): "The Art of Verification with VERA" - Keating and Bricaud (1999): "Reuse Methodology Manual" - Bergeron (2000): "Writing Testbenches. Functional Verification of HDL Models"                                                                                                                                                                                                                                                              |                                                      |                   |                                      |
| Further references will be announced in the course.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                      |                   |                                      |



| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Verification, Validation and Testing of ASIC Designs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4,0        | Lecture/Exercise | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
| <p>- Wagner and Bertacco (2011): "Post-Silicon and Runtime Verification for Modern Processors" - Wang, Stroud, and Toubia (2008): "System-on-Chip Test Architectures: Nanometer Design for Testability" - Mishra and Dutt (2005): "Functional Verification of Programmable Embedded Architectures: A Top-Down Approach" - Haque, Khan, and Michelson (2001): "The Art of Verification with VERA" - Keating and Bricaud (1999): "Reuse Methodology Manual" - Bergeron (2000): "Writing Testbenches. Functional Verification of HDL Models" Weitere Referenzen werden in der Veranstaltung bekannt gegeben.</p> |            |                  |                 |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Memory Systems                                                                                              |                   |                               |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 4211460                                                                                                     | Module version    | V2                            |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                             | Language          | english                       |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the summer term                                                                                     | Teaching unit     | Carl-Friedrich-Gauß-Fakultät  |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                                                                                                           | Institution       |                               |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 4 / 5,0                                                                                                     | Module owner      | Prof. Dr. Guillermo Payá Vayá |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                                                                                                         |                   |                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 56                                                                                                          | Self studying (h) | 94                            |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                             |                   |                               |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | The module “Application-Specific Instruction-Set Processors” is recommended as preparation for this course. |                   |                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Graded work (examination): Written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam.           |                   |                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                             |                   |                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                             |                   |                               |
| 1. Introduction to Memory Systems (Review)<br>2. Overview on Memory Technology<br>2.1 Volatile Memories: SRAM, DRAM<br>2.2 Non-volatile Memories: ROM, Flash Memory, F-RAM, MRAM,...<br>3. Main Memory: Interfaces, Commands, and Controllers<br>4. Memory Cache<br>5. Processing-in-Memory (PIM) / New Data Processing<br>5.1 Using traditional and 3D-Stacked memories<br>5.2 Low-latency interfaces                                                                                                                                                                                      |                                                                                                             |                   |                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                             |                   |                               |
| This course focusses on the main challenges for the design of modern semiconductor storage systems under the aspect of rapidly growing data storage requirements. Current, volatile and non-volatile memory types will be covered from the fundamental semiconductor technology level up to higher levels of system-level abstraction, with a focus on reliability and protection of stored data. Furthermore, Processing-in-Memory Architectures (PIM) based on conventional and 3D-stacked memories are analyzed, taking into account aspects such as low latency and energy consumption. |                                                                                                             |                   |                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                             |                   |                               |
| <ul style="list-style-type: none"><li>• Balasubramonian (2019): "Innovations in the Memory Systems", Morgan &amp; Claypool Publishers</li><li>• Hennessy and Patterson (2017): "Computer Architecture. A Quantitative Approach", 6th Edition, Morgan Kaufmann</li><li>• Jacob, Ng, and Wang (2008): "Memory Systems: Cache, DRAM, Disk", Morgan Kaufmann "</li></ul>                                                                                                                                                                                                                        |                                                                                                             |                   |                               |
| Further references will be announced in the course.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                             |                   |                               |



|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Memory Systems                                                                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Balasubramonian (2019): "Innovations in the Memory Systems", Morgan &amp; Claypool Publishers</li> <li>- Hennessy and Patterson (2017): "Computer Architecture. A Quantitative Approach", 6th Edition, Morgan Kaufmann</li> <li>- Jacob, Ng, and Wang (2008): "Memory Systems: Cache, DRAM, Disk", Morgan Kaufmann "</li> </ul> <p>Further references will be announced in the course.</p> |            |                  |                 |
| Memory Systems                                                                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Exercise         | english         |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Advanced FPGA-Design                                                                                                                         |                   |                               |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4211510                                                                                                                                      | Module version    | V2                            |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                              | Language          | english german                |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | only in the winter term                                                                                                                      | Teaching unit     | Carl-Friedrich-Gauß-Fakultät  |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1 Semester                                                                                                                                   | Institution       |                               |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 4 / 5,0                                                                                                                                      | Module owner      | Prof. Dr. Guillermo Payá Vayá |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 150                                                                                                                                          |                   |                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 56                                                                                                                                           | Self studying (h) | 94                            |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                              |                   |                               |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | The courses “Hardware-Software-Systems”, “Digital Circuits Design”, and “Hardware Praktikum” are recommended as preparation for this course. |                   |                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1 graded work: Written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam                                                         |                   |                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                              |                   |                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                              |                   |                               |
| 1. Introduction to Reconfigurable Computing<br>2. FPGA Basic Architecture (incl. DSP blocks, embedded memories, soft and hard processors) (Review)<br>3. Additional Architectural Elements of FPGAs (Boundary scan, I/O cells (PLLs), MIG, transceivers, analog-to-digital converters, ...)<br>4. FPGA Memory Technologies (SRAM, EPROM, Flash, Anti-Fuse, MRAM)<br>5. High-Performance Circuit Design on FPGAs<br>6. Dynamic and Partial Reconfiguration Mechanisms (incl. Space-Time FPGAs)<br>7. Design Tools for FPGAs (incl. VTR)<br>8. FPGA-Based Applications                                                                  |                                                                                                                                              |                   |                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                              |                   |                               |
| After completing the module, the students know how to design and optimize complex circuits on modern FPGA devices. Moreover, they are capable to efficiently use all the embedded dedicated hardware modules, e.g., DSPs, different embedded memories, I/O high speed interfaces, or analog-to-digital converters. This course makes emphasis on the design of high performance circuits by understanding the FPGA architecture limitations and including dynamic and partial reconfiguration mechanisms. The students will be introduced to emerging reconfigurable logic devices and their use in demanding technical applications. |                                                                                                                                              |                   |                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                              |                   |                               |
| - Palchadhuri, A.; Chakraborty, R.S.; „High Performance Integer Arithmetic Circuit Design on FPGA“, Springer, 2016<br><br>- Deschamps, J-P.; Sutter, G.D.; Cantó, E. : „Guide to FPGA Implementation of Arithmetic Functions“, Springer, 2012<br><br>- Rodriguez-Andina, J.J.; et. al.: „FPGAs. Fundamentals, Advanced Features, and Applications in Industrial Electronics“, CRC Press, 2017<br><br>- Ashenden, P.: "The Designers Guide to VHDL", Morgan Kaufmann, 3rd revised edition, November 2006                                                                                                                               |                                                                                                                                              |                   |                               |



- Bergeron, J.: "Writing Testbenches: Functional Verification of HDL Models", Springer-Verlag, 2003
- Betz, V.; Rose, J.; Marquardt, A.: "Architecture and CAD for Deep-Submicron FPGAs", Kluwer, 1999
- Bobda, C.: "Introduction to Reconfigurable Computing", Springer-Verlag, 2007
- Grout, I.: "Digital System Design with FPGAs and CPLDs", Elsevier Science & Technology, 2008
- Hunter, R.; Johnson, T.: "VHDL", Springer-Verlag, 2007
- Meyer-Baese, U.: "Digital Signal Processing with Field Programmable Gate Arrays", Springer-Verlag, 2007
- Rahman, A.: "FPGA based Design and applications", Springer-Verlag, 2008
- Sikora, A.: "Programmierbare Logikbauelemente", Hanser-Verlag, 2001
- Wilson, P.: "Design Recipes for FPGAs", Elsevier Science & Technology, 2007

Further references will be announced in the course



| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |                  |                |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------------|----------------|
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |                  |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |     |                  |                |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |     |                  |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |     |                  |                |
| Name of the course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | SWS | Eventtype        | Language       |
| Advanced FPGA-Design                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4,0 | Lecture/Exercise | english german |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |     |                  |                |
| <p>- Palchaudhuri, A.; Chakraborty, R.S.; „High Performance Integer Arithmetic Circuit Design on FPGA“, Springer, 2016 - Deschamps, J-P.; Sutter, G.D.; Cantó, E.: „Guide to FPGA Implementation of Arithmetic Functions“, Springer, 2012 - Rodriguez-Andina, J.J.; et. al.: „FPGAs. Fundamentals, Advanced Features, and Applications in Industrial Electronics“, CRC Press, 2017 - Ashenden, P.: "The Designers Guide to VHDL", Morgan Kaufmann, 3rd revised edition, November 2006 - Bergeron, J.: "Writing Testbenches: Functional Verification of HDL Models", Springer-Verlag, 2003 - Betz, V.; Rose, J.; Marquardt, A.: "Architecture and CAD for Deep-Submicron FPGAs", Kluwer, 1999 - Bobda, C.: "Introduction to Reconfigurable Computing", Springer-Verlag, 2007 - Grout, I.: "Digital System Design with FPGAs and CPLDs", Elsevier Science &amp; Technology, 2008 - Hunter, R.; Johnson, T.: "VHDL", Springer-Verlag, 2007 - Meyer-Baese, U.: "Digital Signal Processing with Field Programmable Gate Arrays", Springer-Verlag, 2007 - Rahman, A.: "FPGA based Design and applications", Springer-Verlag, 2008 - Sikora, A.: "Programmierbare Logikbauelemente", Hanser-Verlag, 2001 - Wilson, P.: "Design Recipes for FPGAs", Elsevier Science &amp; Technology, 2007 (EN) Further references will be announced in the course</p> |     |                  |                |

**Major Specialisation: Energy Systems and Drive Technologies/Powertrain - Compulsory Elective Modules**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                  |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Control of Electrical Devices                                                    |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2412680                                                                          | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                  | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the winter term                                                          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                                                | Institution       | Institut für Elektrische Maschinen, Antriebe und Bahnen  |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 4 / 5,0                                                                          | Module owner      | Prof. Dr. Markus Henke                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                                                              |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 56                                                                               | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                  |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | oral exam (30 min) or written exam (60 min), depending on number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                  |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                  |                   |                                                          |
| motion equation and non-stationary movement, heating processes, dynamic behaviour of DC and AC motor drives, servo drives with inverters, control of inverter drives with DC and AC motors, sensor-less field-oriented control                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                  |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                  |                   |                                                          |
| Students understand the models of DC and AC motor drives and the mathematical concept of space vectors and can utilise them in simulations. They know the control structures for the motor types DC motor, asynchronous machine and synchronous machine with and without speed sensor. They can design and analyse their own control structures and tune the control parameters. They understand sensors commonly used in drive systems like compensated current sensor, resolver, incremental angular sensor and the corresponding evaluation functions. They can use the principle of space vector modulation and similar modulation methods to design their own hardware and software. |                                                                                  |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                  |                   |                                                          |
| - W. Leonhard: Regelung elektrischer Antriebe, Springer-Verlag, ISBN: 978-3540671794<br>- W. Leonhard: Control of electrical Drives, Springer-Verlag, ISBN: 978-3540418207                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                  |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                  |                   |                                                          |
| Requirements: Lecture „Fundamentals of control technologies“                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                  |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 2,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Applied Power Electronics                    |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2414230                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                            | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                      | Module owner      | Prof. Dr. Regine Mallwitz                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>• Power electronics and electromagnetic compatibility (EMC)</li><li>• EMC guidelines and filter circuits</li><li>• Power Factor Correction (PFC)</li><li>• Resonant power converters</li><li>• Quasi-resonant circuits</li><li>• Multi-level converters</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |
| After completing the module, students will acquire knowledge of legal requirements regarding electromagnetic compatibility. They will learn the structure, function, application and design of passive and active filter circuits. An important aspect here is to obtain a mains current that is as sinusoidal as possible in phase with the mains voltage with the help of so-called power factor correction (PFC). Students should understand how resonant power converters and quasi-resonant circuits work and how they are used, also by means of simulations. Finally, they should be able to understand the structure and function of multi-level converters. They will be able to conceptually design, dimension and analyse (also by simulation) corresponding assemblies. |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                   |                                                          |
| Grundkurs Leistungselektronik, Joachim Specovius, Vieweg-Verlag<br>Applikationshandbuch Leistungshalbleiter, Semikron, ISLE-Verlag                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |

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|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                 | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                               |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Skript</li> <li>- DIN 41750: "Begriffe für Stromrichter", Beuth Verlag GmbH, 1984</li> <li>- Jötten, R.: "Leistungselektronik", Vieweg Verlag, Braunschweig, 1977</li> <li>- Heumann/Stumpe: "Thyristoren", Teubner Verlag, Stuttgart, 1970</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                 | 2,0        | Exercise         | german          |

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|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                           | A.C. Drive Systems and their Computer Simualtion                                                                         |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2414250                                                                                                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                          | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the summer term                                                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                                                                                                        | Institution       | Institut für Elektrische Maschinen, Antriebe und Bahnen  |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                           | 5 / 5,0                                                                                                                  | Module owner      | Prof. Dr. Markus Henke                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                                                                                                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                            | 70                                                                                                                       | Self studying (h) | 80                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                          |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                        | Knowledge from Fundamentals of Electrical Power Engineering (Part 2: Electromechanical energy conversion) is recommended |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (120 min) or oral exam (30 min)                                                                             |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                          |                   |                                                          |
| <div>- Overview of converter-fed drive systems: energy supply, power semiconductors, motors, loads</div> <div>- Modelling and simulation of the components in the drive system</div> <div>- Application of space vector theory</div> <div>- Hardware in the loop methods</div> <div>- Simulation of electromagnetic converters, numerical simulation programmes</div> <div>- Practical simulation exercises with various simulation tools</div> |                                                                                                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                          |                   |                                                          |
| After completing the module, students can select drive systems and simulate simple electromechanical systems.                                                                                                                                                                                                                                                                                                                                   |                                                                                                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                          |                   |                                                          |
| <div>Schröder D., Elektrische Antriebe - Grundlagen, Springer 2009</div> <div>Seefried / Müller, Frequenzgesteuerte Drehstrom-Asynchronantriebe, Verlag Technik Berlin, 1992</div>                                                                                                                                                                                                                                                              |                                                                                                                          |                   |                                                          |



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|-----------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                              |            |                  |                 |
|                                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                        |            |                  |                 |
|                                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                     | 3,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                   |            |                  |                 |
| R. Fischer, Elektrische Maschinen, Hanser, ISBN-13: 9783446452183<br>Binder A.: Elektrische Maschinen und Antriebe, Springer ISBN 978-3-540-71850-5 |            |                  |                 |
|                                                                                                                                                     | 2,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Electric Power Systems Engineering                                                                         |                   |                                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2423550                                                                                                    | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                            | Language          | english                                                     |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                                                                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                                                                          | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4 / 5,0                                                                                                    | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                                                                                        |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 56                                                                                                         | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                            |                   |                                                             |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | oral examination (30 minutes) or presentation (20 minutes plus scientific talk with examination character) |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                            |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                            |                   |                                                             |
| <ul style="list-style-type: none"><li>• Discussion of power system overvoltages</li><li>• Calculation of electric fields</li><li>• Statistical analysis of ionization and breakdown phenomena</li><li>• Calculation of the breakdown of gases (SF6), liquids (insulating oil), solids, and composite materials, as well as the breakdown characteristics of long air gaps</li><li>• Description of insulation systems currently used in high-voltage engineering, including air insulation and insulators in overhead power transmission lines, gas-insulated substation (GIS) and cables, oil-paper insulation in power transformers, paper-oil insulation in high-voltage cables, and polymer insulation in cables</li><li>• Examination of contemporary practices in insulation coordination in association with the International Electrotechnical Commission (IEC) definition and the latest standards.</li></ul>                                                                                                                         |                                                                                                            |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                            |                   |                                                             |
| <p>The students have fundamental knowledge of Power Systems and special or in-depth expertise for High-Voltage Systems Engineering.</p> <p>They learn methods with the help of discipline experiments and simulations and interpret / evaluate texts and data from Power Systems.</p> <p>They are able to make scientifically sound judgments within the scope of High-Voltage and formulate research problems.</p> <p>The students are able to select an adequate level of abstraction for a given research problem and work on that level.</p> <p>They can assess the scientific value of High-Voltage research and can formulate development or application problems.</p> <p>For Power Systems Engineering they have a systematic approach characterized by the application and development of theories, models and coherent interpretations and they can use scientific theories / model concepts.</p> <p>They reflect critically on their own way of thinking, their decisions and actions and are able to think logically (recognize</p> |                                                                                                            |                   |                                                             |



fallacies and deceptions) and critically interpret scientific data (origin, completeness, relevance, etc.) and formulate a wellfounded opinion.  
 They can communicate to others in writing and orally the results of the scientific work in the given examples and behave professionally (in the sense of reliability, commitment, correctness, precise work, perseverance, independence, etc.).  
 The students work task-related and target-oriented in the learning group and deal with group-dynamic processes. They analyze social, economic or cultural consequences of new developments in High-Voltage Transmission.

#### Literature

- High Voltage Engineering Farouk A.M. Rizk, Giao N. Trinh CRC Press 2014
- High Voltage Engineering: Fundamentals - Technology - Applications Küchler, Andreas VDI-Buch 2018



#### Related courses

#### Rules for the choice of courses

#### Compulsory attendance

| Name of the course                                                                                                                                                        | SWS | Eventtype | Language |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----------|----------|
|                                                                                                                                                                           | 2,0 | Lecture   | english  |
| <b>Literature</b>                                                                                                                                                         |     |           |          |
| High Voltage Engineering Farouk A.M. Rizk, Giao N. Trinh CRC Press 2014 High Voltage Engineering: Fundamentals - Technology - Applications Küchler, Andreas VDI-Buch 2018 |     |           |          |
|                                                                                                                                                                           | 2,0 | Exercise  | english  |

| Title                                                                                                                                                                                                                                                                            | Electrical Systems and Grids                 |                   |                                                             |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                           | 2423560                                      | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                        |                                              | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                               | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                  | 1                                            | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                            | 3 / 5,0                                      | Module owner      | Prof. Dr. Bernd Engel                                       |
| Workload (h)                                                                                                                                                                                                                                                                     | 150                                          |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                             | 42                                           | Self studying (h) | 108                                                         |
| Compulsory requirements                                                                                                                                                                                                                                                          |                                              |                   |                                                             |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                     | oral exam (30 min) or written exam (120 min) |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                               |                                              |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                         |                                              |                   |                                                             |
| Line and network types<br>Equivalent circuits of the networks<br>Electrical characteristics of the equipment<br>Calculation of lines and networks<br>Network control<br>Short circuit and load flow calculation<br>Stability<br>Protective measures                              |                                              |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                          |                                              |                   |                                                             |
| After completing the module, students will be able to understand the structure and operation of electrical power supply networks from extra-high to low voltage. The basics they have learnt enable them to independently analyse networks in the event of operation and faults. |                                              |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                       |                                              |                   |                                                             |
| Elektrische Energieversorgung, K. Heuck, Vieweg Elektrische Kraftwerke und Netze, D. Oeding, Springer                                                                                                                                                                            |                                              |                   |                                                             |

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|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|  |     |          |        |
|--|-----|----------|--------|
|  | 1,0 | Exercise | german |
|  | 2,0 | Lecture  | german |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                       |                   |                                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|-------------------|-------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Introduction to power grid technology |                   |                                                             |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2423000020                            | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                       | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the winter term               | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                     | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4 / 5,0                               | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                   |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 70                                    | Self studying (h) | 80                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                       |                   |                                                             |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Oral exam 30 min.                     |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                       |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                       |                   |                                                             |
| <ul style="list-style-type: none"><li>• Nodes in the network, all voltage levels</li><li>• Basics of networks: Grounding system, Error types</li><li>• Isolation Coordination</li><li>• Thermal and mechanical stress</li><li>• Protection Systems</li><li>• Switching operations: Component network interface</li><li>• Switches: AC and DC extinguishing principle</li><li>• Fundamentals of Plasma Technology</li><li>• Vacuum switch</li><li>• Gas switch</li><li>• DC Voltage Switches</li><li>• Transformer</li><li>• Structure of switchgear and basic circuits used</li></ul>                                        |                                       |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                       |                   |                                                             |
| After successful completion of the module, students will have knowledge of key technologies, structure and function of future power grids. They are able to understand their complex interaction and derive requirements for components in order to ensure the operation and protection of the power grids in a wide variety of system states. In addition, they are able to apply the knowledge imparted in the design of switches at all voltage levels for direct and alternating current of the power grids. On the basis of excursions and exercises, the knowledge is applied and insights into practice are provided. |                                       |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                       |                   |                                                             |
| Adil Erk und Martin Schmelzle. Grundlagen der Schaltgerätetechnik: Kontaktglieder und Löscheinrichtungen elektrischer Schaltgeräte der Energietechnik. Berlin: Springer, 1974. ISBN: 3-540-06075-8                                                                                                                                                                                                                                                                                                                                                                                                                           |                                       |                   |                                                             |
| W. Rieder. Plasma und Lichtbogen. Braunschweig: Friedr. Vieweg & Sohn GmbH, 1967                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                       |                   |                                                             |
| Josef Lutz. Halbleiter-Leistungsbaulemente: Physik, Eigenschaften, Zuverlässigkeit. 2. Aufl. Berlin and Heidelberg: Springer Vieweg, 2012. ISBN: 978-3-642-29795-3                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                       |                   |                                                             |

Andreas Küchler. Hochspannungstechnik: Grundlagen - Technologie -Anwendungen. 3., neu bearbeitete und erweiterte Auflage. VDI-Buch. Heidelberg et al.: Springer, 2009. ISBN: 978- 3-540-78412-8

Stefan Kopatsch und Gerald Kopatsch. ABB Schaltanlagen-Handbuch 13. Auflage. Wurth und Körner, Werbung und Design, 68163 Mannheim

**Remark**

This module replaces "Elektrische Energieanlagen 2/Betriebsmittel" ("Electrical Power Systems 2").



|                                                                                                                                                                                                    |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                             |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                                    |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                       |            |                  |                 |
|                                                                                                                                                                                                    |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                          | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Introduction to power grid technology                                                                                                                                                              | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                  |            |                  |                 |
| Adil Erk und Martin Schmelzle. Grundlagen der Schaltgerätetechnik: Kontaktglieder und Löscheinrichtungen elektrischer Schaltgeräte der Energietechnik. Berlin: Springer, 1974. ISBN: 3-540-06075-8 |            |                  |                 |
| W. Rieder. Plasma und Lichtbogen. Braunschweig: Friedr. Vieweg & Sohn GmbH, 1967                                                                                                                   |            |                  |                 |
| Josef Lutz. Halbleiter-Leistungsbaulemente: Physik, Eigenschaften, Zuverlässigkeit. 2. Aufl. Berlin and Heidelberg: Springer Vieweg, 2012. ISBN: 978-3-642-29795-3                                 |            |                  |                 |
| Andreas Küchler. Hochspannungstechnik: Grundlagen - Technologie -Anwendungen. 3., neu bearbeitete und erweiterte Auflage. VDI-Buch. Heidelberg et al.: Springer, 2009. ISBN: 978- 3-540-78412-8    |            |                  |                 |
| Stefan Kopatsch und Gerald Kopatsch. ABB Schaltanlagen-Handbuch 13. Auflage. Wurth und Körner, Werbung und Design, 68163 Mannheim                                                                  |            |                  |                 |
| Introduction to power grid technology                                                                                                                                                              | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                  |            |                  |                 |
| Adil Erk und Martin Schmelzle. Grundlagen der Schaltgerätetechnik: Kontaktglieder und Löscheinrichtungen elektrischer Schaltgeräte der Energietechnik. Berlin: Springer, 1974. ISBN: 3-540-06075-8 |            |                  |                 |
| W. Rieder. Plasma und Lichtbogen. Braunschweig: Friedr. Vieweg & Sohn GmbH, 1967                                                                                                                   |            |                  |                 |
| Josef Lutz. Halbleiter-Leistungsbaulemente: Physik, Eigenschaften, Zuverlässigkeit. 2. Aufl. Berlin and Heidelberg: Springer Vieweg, 2012. ISBN: 978-3-642-29795-3                                 |            |                  |                 |
| Andreas Küchler. Hochspannungstechnik: Grundlagen - Technologie -Anwendungen. 3., neu bearbeitete und erweiterte Auflage. VDI-Buch. Heidelberg et al.: Springer, 2009. ISBN: 978- 3-540-78412-8    |            |                  |                 |
| Stefan Kopatsch und Gerald Kopatsch. ABB Schaltanlagen-Handbuch 13. Auflage. Wurth und Körner, Werbung und Design, 68163 Mannheim                                                                  |            |                  |                 |

**Major Specialisation: Energy Systems and Drive Technologies/Powertrain - Elective Modules**

|                                                                                                                                                                                                                                                                                                         |                                                                                          |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                   | Advanced Control Engineering                                                             |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                  | 2412390                                                                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                               |                                                                                          | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                      | only in the summer term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                         | 1                                                                                        | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                   | 4 / 5,0                                                                                  | Module owner      | Prof. Dr. Markus Maurer                                  |
| Workload (h)                                                                                                                                                                                                                                                                                            | 150                                                                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                    | 56                                                                                       | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                 | Prerequisite: Lecture "Fundamentals of Control Engineering"                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                               | oral exam (30 minutes) or written exam (60 minutes), depending on number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                      |                                                                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                          |
| Continuation and application of linear control theory, meshed control loops, multivariable control, simple nonlinear control systems: two- and three-step controllers, state space equations, state space control, state space, description function, stability criteria for nonlinear control systems. |                                                                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                 |                                                                                          |                   |                                                          |
| After completing the module, students are able to apply advanced control engineering knowledge in the area of multivariable control of linear systems in state space (state controller, observer, disturbance compensation).                                                                            |                                                                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                              |                                                                                          |                   |                                                          |
| - Lecture notes<br>- J. Lunze: Regelungstechnik 2, Springer-Verlag, ISBN: 978-3540784623<br>- O. Föllinger: Nichtlineare Regelungen 1 & 2, Hüthig-Verlag, ISBN: 978-3486245271 & 978-3486225037<br>- W. Leonhard: Einführung in die Regelungstechnik, Vieweg-Verlag, ISBN: 978-3528535841               |                                                                                          |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                  |                                                                                          |                   |                                                          |
| Prerequisite: Lecture "Fundamentals of Control Engineering"                                                                                                                                                                                                                                             |                                                                                          |                   |                                                          |

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|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Exercise         | german          |
|                                        | 2,0        | Lecture          | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Control of Electric Power Systems                                                        |                   |                                                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2412450                                                                                  | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                          | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | only in the winter term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1                                                                                        | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 4 / 5,0                                                                                  | Module owner      | Dr. Stefan Laudahn                                          |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 150                                                                                      |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 56                                                                                       | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                          |                   |                                                             |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | BSc lecture Fundamentals of Control Engineering                                          |                   |                                                             |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | oral examination (30 min) or written exam (120 min), depending on number of participants |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                          |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                          |                   |                                                             |
| The lecture topics are also taught in the weekly exercise in practical simulations with Matlab/Simulink. Previous knowledge of Matlab/Simulink is not required and will be taught during the course.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                          |                   |                                                             |
| Contents of the course:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                          |                   |                                                             |
| <ul style="list-style-type: none"><li>• Introduction to grid control</li><li>• Power transmission in the three-phase grid</li><li>• Frequency and voltage control of synchronous generators in power plants</li><li>• Simulation of conventional power plants in Matlab/Simulink (exercise)</li><li>• Frequency and voltage control in electrical grids</li><li>• Basics of the control of power converters</li><li>• Grid-following and grid-forming converter control</li><li>• Simulation of converter-based renewable energies in Matlab/Simulink (exercise)</li><li>• Implementation of grid functions (P(f), Q(U), FRT, ...) in the power converters</li><li>• Fundamentals of the control of DC systems, especially battery storage systems</li><li>• Weekly implementation of the learned controls in Matlab/Simulink (simulation software)</li></ul> |                                                                                          |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                          |                   |                                                             |
| After completing the module, students have a basic overall understanding of the control of conventional and renewable energy generation systems and the control of electrical grids. Physical principles of power transmission and mechanisms for maintaining stationary and dynamic grid stability are learnt. Students will be familiar with methods for controlling grids and synchronous generators as well as for hardware-based and higher-level control of converter-coupled renewable energies. This enables students to assess these in terms of their effect on grid stability. Students are also able to simulate the control of conventional power plants and renewable energies as well as power grids. Furthermore, they are able to transfer technical grid connection requirements into control mechanisms and develop grid functions.        |                                                                                          |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                          |                   |                                                             |



- W. Leonhard: Regelung in der elektrischen Energieversorgung, Teubner-Verlag, ISBN: 978-3519061090

- Paul Denzel: „Grundlagen der Übertragung elektrischer Energie“, Springer-Verlag Berlin Heidelberg, 1966, eBook ISBN: 978-3-642-86899-3

**Remark**



|                                                                                                   |            |                  |                 |
|---------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                            |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                            |            |                  |                 |
| German                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                      |            |                  |                 |
|                                                                                                   |            |                  |                 |
| <b>Name of the course</b>                                                                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                   | 2,0        | Exercise         | german          |
|                                                                                                   | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                 |            |                  |                 |
| W. Leonhard: Regelung in der elektrischen Energieversorgung, Teubner-Verlag, ISBN: 978-3519061090 |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                  |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Control of Electrical Devices                                                    |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2412680                                                                          | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                  | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the winter term                                                          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                                                | Institution       | Institut für Elektrische Maschinen, Antriebe und Bahnen  |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 4 / 5,0                                                                          | Module owner      | Prof. Dr. Markus Henke                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                                                              |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 56                                                                               | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                  |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | oral exam (30 min) or written exam (60 min), depending on number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                  |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                  |                   |                                                          |
| motion equation and non-stationary movement, heating processes, dynamic behaviour of DC and AC motor drives, servo drives with inverters, control of inverter drives with DC and AC motors, sensor-less field-oriented control                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                  |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                  |                   |                                                          |
| Students understand the models of DC and AC motor drives and the mathematical concept of space vectors and can utilise them in simulations. They know the control structures for the motor types DC motor, asynchronous machine and synchronous machine with and without speed sensor. They can design and analyse their own control structures and tune the control parameters. They understand sensors commonly used in drive systems like compensated current sensor, resolver, incremental angular sensor and the corresponding evaluation functions. They can use the principle of space vector modulation and similar modulation methods to design their own hardware and software. |                                                                                  |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                  |                   |                                                          |
| - W. Leonhard: Regelung elektrischer Antriebe, Springer-Verlag, ISBN: 978-3540671794<br>- W. Leonhard: Control of electrical Drives, Springer-Verlag, ISBN: 978-3540418207                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                  |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                  |                   |                                                          |
| Requirements: Lecture „Fundamentals of control technologies“                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                  |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 2,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                              | Electrical Machines and Drives                       |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                             | 2414180                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                          |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                 | only in the winter term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                    | 1                                                    | Institution       | Institut für Elektrische Maschinen, Antriebe und Bahnen  |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                              | 4 / 5,0                                              | Module owner      | Prof. Dr. Markus Henke                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                       | 150                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                               | 56                                                   | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                       | Written exam (120 minutes) or oral exam (30 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                 |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                           |                                                      |                   |                                                          |
| <div>- Speed and torque control of direct current and three-phase drives with power electronic control circuits</div> <div>- Operating behaviour of permanent magnet and salient pole synchronous machines</div> <div>- Modelling of electrical machines and drives</div> <div>- Design and control of magnetic bearings</div>                                     |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                                          |
| After completing the Electrical Drives module, students will have an overview of the functions of the most important DC and mmost important direct current and rotating field machines. The in-depth fundamentals enable the assessment of existing motor and generator drives as well as the design of simple drive systems for industry and mobile applications. |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| Binder, Elektrische Maschinen und Antriebe: Grundlagen, Betriebsverhalten, Springer<br>Schröder D., Elektrische Antriebe Grundlagen, Springer<br>Hofmann W., Elektrische Maschinen, Pearson<br>Hagl, Elektrische Antriebstechnik, Hanser                                                                                                                           |                                                      |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|                                                                                                |     |          |        |
|------------------------------------------------------------------------------------------------|-----|----------|--------|
|                                                                                                | 2,0 | Exercise | german |
| <b>Literature</b>                                                                              |     |          |        |
| Skript                                                                                         |     |          |        |
|                                                                                                | 2,0 | Lecture  | german |
| <b>Literature</b>                                                                              |     |          |        |
| Skript, H.O. Seinsch, Ausgleichsvorgänge bei elektrischen Antrieben, Teubner Verlag, Stuttgart |     |          |        |

|                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                      | Basic Circuits of Power Electronics          |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                     | 2414190                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                  |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                         | only in the winter term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                            | 1                                            | Institution       | Institut für Elektrische Maschinen, Antriebe und Bahnen  |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                      | 4 / 5,0                                      | Module owner      | Prof. Dr. Regine Mallwitz                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                               | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                       | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                  | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                         |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>• Components of power electronics</li><li>• Simulation of power electronics</li><li>• Dimensioning of chokes and transformers</li><li>• Functionality and design of DC converters and switching power supplies</li><li>• Control and protective circuitry of power semiconductors</li><li>• Power loss and cooling of power semiconductors</li></ul> |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
| After completing the module, students will have acquired basic knowledge of the structure, function, application and design of passive components in power electronics. They will be able to independently design and dimension complete power electronics circuit arrangements.                                                                                                           |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                 |                                              |                   |                                                          |
| Schaltnetzteile und ihre Peripherie, Ulrich Schlienz, Vieweg-Verlag                                                                                                                                                                                                                                                                                                                        |                                              |                   |                                                          |



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|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

|                                                                                                                              |     |          |        |
|------------------------------------------------------------------------------------------------------------------------------|-----|----------|--------|
|                                                                                                                              | 2,0 | Exercise | german |
|                                                                                                                              | 2,0 | Lecture  | german |
| <b>Literature</b>                                                                                                            |     |          |        |
| Jürgen Meins: "Elektromechnik", B.G. Teubner Verlag 1997 Schaltnetzteile und ihre Peripherie, Ulrich Schlienz, Vieweg-Verlag |     |          |        |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Design of Electrical Machines                |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2414200                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | only in the winter term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1                                            | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 4 / 5,0                                      | Module owner      | Prof. Dr. Markus Henke                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                          | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>• Force and torque buildup in electrical machines</li><li>• Winding design of rotating field machines</li><li>• Winding factor calculation</li><li>• Fundamentals of thermal modelling of electrical machines</li><li>• Cooling mechanisms</li><li>• Finite element methods for electromagnetic machine design</li><li>• Analytical design of electrical machines</li><li>• Motor topologies for automotive and aviation applications</li></ul> |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |                   |                                                          |
| After completing the module, the students have in-depth knowledge of the function of rotating electric machines and the physical intervention options for speed control. The deepened fundamentals enable the design of simple drives taking into account possible fault conditions as well as the entry into the design of electrical machines.                                                                                                                                      |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| Binder, Elektrische Maschinen und Antriebe: Grundlagen, Betriebsverhalten, Springer<br>G. Müller, B. Ponick: Theorie elektrischer Maschinen, VCH<br>H.O. Seinsch, Ausgleichsvorgänge bei elektrischen Antrieben, Teubner Verlag, Stuttgart                                                                                                                                                                                                                                            |                                              |                   |                                                          |

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| <b>Related courses</b>                                                                                                                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                          | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                        |            |                  |                 |
| G. Müller, Theorie elektrischer Maschinen, VCH Verlagsgesellschaft mbH, ISBN: 3-527-28392-7 H.O. Seinsch, Ausgleichsvorgänge bei elektrischen Antrieben, Teubner Verlag, Stuttgart, 1991 |            |                  |                 |
|                                                                                                                                                                                          | 2,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Drives for Electric Road Vehicles            |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2414220                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the winter term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                                            | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 4 / 5,0                                      | Module owner      | Prof. Dr. Markus Henke                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
| The module teaches a system-oriented approach to the design of electric drives in road vehicles by considering the vehicle as a mechatronic system. Starting from the basics of drive design (driving resistances, power transmission), common drive topologies of road vehicles are dealt with. Special features of the motors used with regard to their function and their properties as inverter-fed drives are dealt with. The knowledge gained here on the design and dimensioning of traction drives is then applied to road vehicles (electric and hybrid vehicles). |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |
| After completing the module, the students know the essential structures of conventional and new types of vehicle drives and the electrical machines and converters used in these vehicles. They are also able to carry out a simple design.                                                                                                                                                                                                                                                                                                                                 |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| Babiel, Elektrische Antriebe in der Fahrzeugtechnik, Vieweg<br>Reif, Noreikat, Bergeest, Kraftfahrzeug-Hybridantriebe, Springer                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |



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|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |
|                                        | 1,0 | Lecture   | german   |

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|  | 1,0 | Lecture  | german |
|  | 2,0 | Exercise | german |

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| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Applied Power Electronics                    |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2414230                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                            | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                      | Module owner      | Prof. Dr. Regine Mallwitz                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>• Power electronics and electromagnetic compatibility (EMC)</li><li>• EMC guidelines and filter circuits</li><li>• Power Factor Correction (PFC)</li><li>• Resonant power converters</li><li>• Quasi-resonant circuits</li><li>• Multi-level converters</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |
| After completing the module, students will acquire knowledge of legal requirements regarding electromagnetic compatibility. They will learn the structure, function, application and design of passive and active filter circuits. An important aspect here is to obtain a mains current that is as sinusoidal as possible in phase with the mains voltage with the help of so-called power factor correction (PFC). Students should understand how resonant power converters and quasi-resonant circuits work and how they are used, also by means of simulations. Finally, they should be able to understand the structure and function of multi-level converters. They will be able to conceptually design, dimension and analyse (also by simulation) corresponding assemblies. |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                   |                                                          |
| Grundkurs Leistungselektronik, Joachim Specovius, Vieweg-Verlag<br>Applikationshandbuch Leistungshalbleiter, Semikron, ISLE-Verlag                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |

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| <b>Related courses</b>                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                 | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                               |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Skript</li> <li>- DIN 41750: "Begriffe für Stromrichter", Beuth Verlag GmbH, 1984</li> <li>- Jötten, R.: "Leistungselektronik", Vieweg Verlag, Braunschweig, 1977</li> <li>- Heumann/Stumpe: "Thyristoren", Teubner Verlag, Stuttgart, 1970</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                 | 2,0        | Exercise         | german          |

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| Title                                                                                                                                                                                                                                                                                                                                                                                                                                           | A.C. Drive Systems and their Computer Simualtion                                                                         |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2414250                                                                                                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                          | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the summer term                                                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                                                                                                        | Institution       | Institut für Elektrische Maschinen, Antriebe und Bahnen  |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                           | 5 / 5,0                                                                                                                  | Module owner      | Prof. Dr. Markus Henke                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                                                                                                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                            | 70                                                                                                                       | Self studying (h) | 80                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                          |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                        | Knowledge from Fundamentals of Electrical Power Engineering (Part 2: Electromechanical energy conversion) is recommended |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (120 min) or oral exam (30 min)                                                                             |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                          |                   |                                                          |
| <div>- Overview of converter-fed drive systems: energy supply, power semiconductors, motors, loads</div> <div>- Modelling and simulation of the components in the drive system</div> <div>- Application of space vector theory</div> <div>- Hardware in the loop methods</div> <div>- Simulation of electromagnetic converters, numerical simulation programmes</div> <div>- Practical simulation exercises with various simulation tools</div> |                                                                                                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                          |                   |                                                          |
| After completing the module, students can select drive systems and simulate simple electromechanical systems.                                                                                                                                                                                                                                                                                                                                   |                                                                                                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                          |                   |                                                          |
| <div>Schröder D., Elektrische Antriebe - Grundlagen, Springer 2009</div> <div>Seefried / Müller, Frequenzgesteuerte Drehstrom-Asynchronantriebe, Verlag Technik Berlin, 1992</div>                                                                                                                                                                                                                                                              |                                                                                                                          |                   |                                                          |

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| <b>Related courses</b>                                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                              |            |                  |                 |
|                                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                        |            |                  |                 |
|                                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                     | 3,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                   |            |                  |                 |
| R. Fischer, Elektrische Maschinen, Hanser, ISBN-13: 9783446452183<br>Binder A.: Elektrische Maschinen und Antriebe, Springer ISBN 978-3-540-71850-5 |            |                  |                 |
|                                                                                                                                                     | 2,0        | Exercise         | german          |

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| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Advanced Power Electronics                   |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2414300                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the winter term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                            | Institution       | Institut für Elektrische Maschinen, Antriebe und Bahnen  |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 4 / 5,0                                      | Module owner      | Prof. Dr. Regine Mallwitz                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>- Requirements analysis</li><li>- DC converters without and with transformer, bidirectional concepts</li><li>- Multi-parallel converters</li><li>- Single-phase and three-phase inverters, design variants, modulation types, bidirectionality</li><li>- Active and passive power electronic components: electrical and thermal properties, measurement technology for characterization, reliability, service life</li></ul>                                                                                                                      |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              |                   |                                                          |
| After completing the module, students will be able to derive the requirements for power electronics from the requirements of an application. They will learn to create concepts for power electronics and to analyse and design suitable circuits. Building on the basic knowledge from the previous power electronics modules (Fundamentals of Power - part of GENT - and Basic Circuits of Power Electronics), alternative circuits are presented and analysed. The knowledge of power electronic components is expanded and supplemented by aspects of reliability and service life. |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |                   |                                                          |
| Dierk Schröder: Leistungselektronische Schaltungen. Springer Verlag.<br>Josef Lutz: Halbleiter-Leistungsbaulemente. Springer Verlag.                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |





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| <b>Related courses</b>                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                              |            |                  |                 |
|                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                        |            |                  |                 |
|                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                     | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                   |            |                  |                 |
| Dierk Schröder: Leistungselektronische Schaltungen. Springer Verlag. Josef Lutz: Halbleiter-Leistungsbau-elemente. Springer Verlag. |            |                  |                 |
|                                                                                                                                     | 2,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Electromagnetic Compatibility               |                   |                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2419120                                     | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                             | Language          | german                                                        |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                           | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3 / 5,0                                     | Module owner      | Prof. Dr. Thomas Kleine-Ostmann<br>Dr. Harald Spieker         |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                         |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 42                                          | Self studying (h) | 108                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written exam (60 min) or oral exam (30 min) |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                               |
| <ul style="list-style-type: none"><li>• Terms and definitions of EMC</li><li>• Sources of interference and disturbance variables, immunity of susceptible devices #</li><li>• Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference #</li><li>• Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection #</li><li>• Legal basis, product liability, standardization #</li><li>• EMC test engineering #</li><li>• Electromagnetic compatibility of biological systems</li></ul> |                                             |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                               |
| The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able assess the EMC product safety by failure mechanisms.    |                                             |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                               |
| <ul style="list-style-type: none"><li>- Lecture notes</li><li>- Joachim Franz, EMV – Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X</li><li>- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1</li><li>- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9</li></ul>                                                                                                                                                                                                                                 |                                             |                   |                                                               |



| <b>Related courses</b>                                                              |            |                  |                 |
|-------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>                                              |            |                  |                 |
| Either this module or "Electromagnetic Compatibility with Seminar" can be selected. |            |                  |                 |
| <b>Compulsory attendance</b>                                                        |            |                  |                 |
|                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Electromagnetic Compatibility                                                       | 2,0        | Lecture          | german          |
| Electromagnetic Compatibility                                                       | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Electromagnetic Compatibility with Seminar                        |                   |                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2419130                                                           | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                   | Language          | english german                                                |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | only in the winter term                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1                                                                 | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 5 / 6,0                                                           | Module owner      | Prof. Dr. Thomas Kleine-Ostmann                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 180                                                               |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 70                                                                | Self studying (h) | 110                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                   |                                                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Written exam (60 min) or oral exam, presentation of seminar topic |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                   |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                   |                   |                                                               |
| <ul style="list-style-type: none"><li>- Terms and definitions of EMC</li><li>- Sources of interference and disturbance variables, immunity of susceptible devices</li><li>- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference</li><li>- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection</li><li>- Legal basis, product liability, standardization</li><li>- EMC test engineering</li><li>- Electromagnetic compatibility of biological systems</li><li>- Current EMC issues presented in seminar talks</li></ul>                                                                    |                                                                   |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                   |                                                               |
| The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able to assess the EMC product safety by failure mechanisms. The students are able to investigate current EMC issues autonomously, structure and present them to an audience. |                                                                   |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                   |                   |                                                               |
| <ul style="list-style-type: none"><li>- continuously updated script handout</li><li>- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X</li><li>- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1</li><li>- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9</li></ul>                                                                                                                                                                                                                                                                                                                            |                                                                   |                   |                                                               |



|                                                                                                                                                                                                                            |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                     |            |                  |                 |
| You can either choose Electromagnetic Compatibility with Seminar <b>or</b> Electromagnetic Compatibility (without seminar). The seminar can also be attended in the summer semester after having attended the EMC lecture. |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Electromagnetic Compatibility                                                                                                                                                                                              | 2,0        | Lecture          | german          |
| Teacher training college EMC                                                                                                                                                                                               | 2,0        | Seminar          | english         |
| Electromagnetic Compatibility                                                                                                                                                                                              | 1,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                     |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | High Voltage Engineering 1                          |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2423360                                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                     | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the winter term                             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                                   | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 4 / 5,0                                             | Module owner      | Prof. Dr. Michael Kurrat                                 |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 56                                                  | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                     |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | oral examination (30 min) or written exam (120 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                     |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                     |                   |                                                          |
| <ul style="list-style-type: none"><li>• Calculation of electric fields in insulation systems</li><li>• Description of the origin and calculation of the propagation of overvoltages in networks</li><li>• Overview of protective measures against overvoltages</li><li>• Introduction to the electrical strength theory of insulation systems</li><li>• Introduction to the statistical calculation of breakdown processes</li><li>• Determination of the electrical strength of insulating gases</li><li>• Description of vacuum breakdown processes</li><li>• Determination of the electrical strength of insulation systems with solid insulating material</li></ul> |                                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                     |                   |                                                          |
| After completing the module, students will be able to fundamentally design and evaluate high-voltage insulation systems.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                     |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                     |                   |                                                          |
| Hochspannungstechnik: Grundlagen-Technologie-Anwendungen, A. Küchler, Springer<br>Elektrische Energieversorgung, K. Heuck, Vieweg                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                     |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

|  |     |          |        |
|--|-----|----------|--------|
|  | 1,0 | Exercise | german |
|  | 3,0 | Lecture  | german |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | System Technology for Photovoltaic                                                      |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2423380                                                                                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                         | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | only in the winter term                                                                 | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1                                                                                       | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 4 / 5,0                                                                                 | Module owner      | Prof. Dr. Bernd Engel                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 150                                                                                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 56                                                                                      | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                         |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | oral exam (30 min) or written exam (90-120 min, in case of high number of participants) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                         |                   |                                                          |
| 1. introduction to the system technology of photovoltaics<br>2. system configurations<br>3. inverter topologies<br>4. functions of the inverters<br>5. other components of PV system technology<br>6. grid integration of PV systems<br>7. off-grid systems<br>8. grid-connected PV systems with storage<br>9. future developments                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                         |                   |                                                          |
| The lecture provides an overview of the requirements for the system components of grid-connected and off-grid photovoltaic systems without and with decentralised battery storage, for example to maximise self-consumption. Due to subsidy programmes and the sharp drop in prices, photovoltaics are becoming increasingly important for the electrical energy supply in Germany (30 gigawatts installed by 2013, share of up to 30 % of the midday load). Special attention is paid to inverter technology with a comparison of the properties of different circuit topologies and their effects on PV system design. In the exercise, PC tool-based system designs and their grid integration are calculated. The lecture is rounded off with a free one-day excursion to the international market and technology leader for solar inverters in Kassel. On completion of the module, students will be able to analyse, assess, design and dimension components and PV systems and their integration into the grid. |                                                                                         |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                         |                   |                                                          |
| Photovoltaik, Heinrich Häberlein, VDE-Verlag, ISBN 978-3-8007-3205-0<br>Photovoltaik für Profis, Falk Antony et. al., Verlag Solarpraxis, ISBN 978-3-934595-38-5<br>Lecture notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                         |                   |                                                          |





|                                                                                                                                                                      |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                               |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                               |            |                  |                 |
|                                                                                                                                                                      |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                         |            |                  |                 |
|                                                                                                                                                                      |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                            | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                      | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                    |            |                  |                 |
| Photovoltaik, Heinrich Häberlein, VDE-Verlag, ISBN 978-3-8007-3205-0 Photovoltaik für Profis, Falk Antony et. al., Verlag Solarpraxis, ISBN 978-3-934595-38-5 Skript |            |                  |                 |
|                                                                                                                                                                      | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                    |            |                  |                 |
| Photovoltaik, Heinrich Häberlein, VDE-Verlag, ISBN 978-3-8007-3205-0 Photovoltaik für Profis, Falk Antony et. al., Verlag Solarpraxis, ISBN 978-3-934595-38-5 Skript |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Electrical Railways     |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2423430                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                         | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the summer term | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                       | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                 | Module owner      | Prof. Dr. Bernd Engel                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                      | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                         |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | oral exam (30 min)      |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                         |                   |                                                          |
| <p>The module provides an overview of electric railway systems and their stationary and mobile electrical components. The closely related electric road bus systems (trolleybus, battery bus with inductive charging) are also considered.</p> <p>are also considered.</p> <p>0 . Repetitorium: Fundamentals of electrical engineering and electrical power engineering for electric railways</p> <p>1 Introduction: Classification of railway vehicles and electric road bus systems</p> <p>2. national and international stationary traction current systems, DC and AC</p> <p>3. electric drives</p> <ul style="list-style-type: none"><li>- Historical development of drive topologies</li><li>- Inverter systems</li><li>- Drive control</li><li>- Traction motors and mechanical drive configurations</li><li>- Internal combustion vehicles/power transmission types</li></ul> <p>4. auxiliary systems</p> <ul style="list-style-type: none"><li>- Heating, air conditioning and ventilation</li><li>- Batteries, local grid feeds</li><li>- Auxiliary converter topologies</li></ul> <p>5. signalling and security systems</p> <ul style="list-style-type: none"><li>- Overview of the most important systems used in Europe</li><li>- On-board equipment</li></ul> <p>6. control technology on railway vehicles</p> <ul style="list-style-type: none"><li>- Tasks: Control and diagnostics</li><li>- Train and vehicle buses and their components</li></ul> <p>7. passenger information and multimedia</p> <p>8 Vehicles operated</p> <p>TRAXX, EuroSprinter, ICE 3, LIREX, ET 423, regional urban railway Regio CITADIS for Kassel, LINT</p> <p>9. future developments</p> <p>Fuel cell, electronic transformer, gearless direct drive, hybrid vehicles, contactless energy transmission</p> <p>energy transmission</p> <p>10. electric road bus systems (trolleybus, battery bus with inductive/conductive charging)</p> |                         |                   |                                                          |

A free one-day excursion to Alstom Transport Deutschland in Salzgitter and to another destination is also offered.

### Objective qualification

After completing the module, students will be able to understand electrical railway systems with regard to the functioning of their components and to evaluate their properties.

### Literature

Andreas Steimel: Elektrische Triebfahrzeuge und ihre Energieversorgung: Grundlagen und Praxis. Oldenbourg Industrieverlag  
Zarko Filipovic: Elektrische Bahnen: Grundlagen, Triebfahrzeuge, Stromversorgung. Springer Verlag  
Biesenack, Hartmut u. a.: Energieversorgung elektrischer Bahnen. Teubner Verlag



### Related courses

#### Rules for the choice of courses

#### Compulsory attendance

| Name of the course | SWS | Eventtype | Language |
|--------------------|-----|-----------|----------|
|--------------------|-----|-----------|----------|

|  |     |          |        |
|--|-----|----------|--------|
|  | 1,0 | Exercise | german |
|--|-----|----------|--------|

### Literature

Andreas Steimel: Elektrische Triebfahrzeuge und ihre Energieversorgung: Grundlagen und Praxis. Oldenbourg Industrieverlag  
Zarko Filipovic: Elektrische Bahnen: Grundlagen, Triebfahrzeuge, Stromversorgung. Springer Verlag  
Biesenack, Hartmut u.a.: Energieversorgung elektrischer Bahnen. Teubner Verlag

|  |     |         |        |
|--|-----|---------|--------|
|  | 3,0 | Lecture | german |
|--|-----|---------|--------|

### Literature

Andreas Steimel: Elektrische Triebfahrzeuge und ihre Energieversorgung: Grundlagen und Praxis. Oldenbourg Industrieverlag  
Zarko Filipovic: Elektrische Bahnen: Grundlagen, Triebfahrzeuge, Stromversorgung. Springer Verlag  
Biesenack, Hartmut u.a.: Energieversorgung elektrischer Bahnen. Teubner Verlag

| Title                                                                                                                                                                                                                                         | Energy Economy and Market Integration of Renewables |                   |                                                             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                                                                                                                                                                        | 2423460                                             | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                     |                                                     | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                            | only in the winter term                             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                               | 1                                                   | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                         | 4 / 5,0                                             | Module owner      | Prof. Dr. Bernd Engel                                       |
| Workload (h)                                                                                                                                                                                                                                  | 150                                                 |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                          | 56                                                  | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                       |                                                     |                   |                                                             |
| Expected performance/<br>Type of examination                                                                                                                                                                                                  | Written exam (120 min) or oral exam (30 min)        |                   |                                                             |
| Course achievement                                                                                                                                                                                                                            |                                                     |                   |                                                             |
| Contents                                                                                                                                                                                                                                      |                                                     |                   |                                                             |
| 1. energy economics<br>2. energy policy<br>3. laws and subsidy systems<br>4. markets (electricity market 2.0, balancing power market)<br>5. direct marketing / balancing group management<br>6. virtual power plant<br>7. large-scale storage |                                                     |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                       |                                                     |                   |                                                             |
| On completion of the module, students will have acquired knowledge of the energy industry in Germany. They will be able to evaluate and assess current developments in the markets. New technologies and research insights are integrated.    |                                                     |                   |                                                             |
| Literature                                                                                                                                                                                                                                    |                                                     |                   |                                                             |
| Marcel Linnemann: Energiewirtschaft für (Quer-)Einsteiger<br>Tim Wawer: Elektrizitätswirtschaft                                                                                                                                               |                                                     |                   |                                                             |

↑

|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|  |     |          |        |
|--|-----|----------|--------|
|  | 2,0 | Lecture  | german |
|  | 2,0 | Exercise | german |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                     |                   |                                                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------|-------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | High Voltage Direct Current Transmission Technology |                   |                                                             |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2423470                                             | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                     | Language          | english                                                     |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the summer term                             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                   | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 4 / 5,0                                             | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                                 |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 56                                                  | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                     |                   |                                                             |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | oral examination (30 min) or written exam (120 min) |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                     |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                     |                   |                                                             |
| <div>-Introduction to HVDC Systems</div> <div>-Thyristors</div> <div>- Six Pulse Diode and Thyristor Converter</div> <div>- HVDC Rectifier Station Modelling, Control and Synchronization with AC System HVDC Inverter Station Modeling and Control</div> <div>- HVDC System V-I Diagrams and Operation Modes</div> <div>- HVDC Phasor Modeling and Interaction with AC System</div> <div>- HVDC Operation with Weak AC Systems</div> <div>- VSC-HVDC Applications, Topologies, Performance, and Cost Comparison with LCC</div> <div>- IGBT Switches and VSC Converter Losses</div> <div>- Single Phase and Three Phase Two-Level VSC Converters</div> <div>- Two Level PWM VSC Converter</div> <div>- VSC-HVDC Applications for AC Grid</div> <div>- HVDC Grids</div>    |                                                     |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                     |                   |                                                             |
| <div>Upon completion of this course, the students shall understand:</div> <div>- The main differences between AC and DC transmission</div> <div>- The main components of HVDC systems</div> <div>- The operation principles of different power semiconductor devices</div> <div>After completing the course, the candidate should be able to:</div> <div>-Establish and modeling of AC and DC sources</div> <div>-Modeling of half wave and full wave rectifiers</div> <div>-Modeling of DC-DC buck converter</div> <div>-Modeling of DC-DC boost converter</div> <div>-Modeling of single phase thyristor converter</div> <div>-Modeling of three phase thyristor converter</div> <div>-Modeling of pulse width modulation (PWM)</div> <div>-Modeling of HVDC link</div> |                                                     |                   |                                                             |

The students will also be able to use PSCAD simulation software in order to simulate different converter models, plotting and analyzing the results. The following abilities should be enhanced through joining the course:

- Work independently and in groups
- Use PSCAD software
- Design and operation of DC-DC converters
- Principles of operation of thyristor single and three phase converters
- Basic principles of controlling HVDC systems
- Fault analysis in HVDC systems
- Operation and control of MTDC systems
- Operation of VSC converters

#### Literature

1. High-Voltage Direct-Current Transmission # Converters, Systems and DC Grids (Dragan Jovcic)
2. HVDC Technology: An Introduction (Michael Kurrat, TU Braunschweig)
3. Power Electronics: A first Course (Ned Mohan)
4. Power System Stability and Control (Prabha Kundur)
5. PSCAD Users Guide

#### Remark

It is recommended that students who intend to join this course have already joined the following courses: Elektrische Energieanlagen I, Grundlagen der elektrischen Energietechnik, Grundlagen der Regelungstechnik



#### Related courses

#### Rules for the choice of courses

#### Compulsory attendance

| Name of the course | SWS | Eventtype | Language |
|--------------------|-----|-----------|----------|
|                    | 2,0 | Lecture   | english  |

#### Literature

1. High-Voltage Direct-Current Transmission ? Converters, Systems and DC Grids (Dragan Jovcic)
2. HVDC Technology: An Introduction (Michael Kurrat, TU Braunschweig)
3. Power Electronics: A first Course (Ned Mohan)
4. Power System Stability and Control (Prabha Kundur)
5. PSCAD Users Guide

|  |     |          |         |
|--|-----|----------|---------|
|  | 2,0 | Exercise | english |
|--|-----|----------|---------|

#### Literature

1. High-Voltage Direct-Current Transmission ? Converters, Systems and DC Grids (Dragan Jovcic)
2. HVDC Technology: An Introduction (Michael Kurrat, TU Braunschweig)
3. Power Electronics: A first Course (Ned Mohan)
4. Power System Stability and Control (Prabha Kundur)
5. PSCAD Users Guide

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                        |                   |                                                             |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------|-------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Design and calculation of DC systems                                                   |                   |                                                             |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2423510                                                                                | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                        | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the winter term                                                                | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                                                                      | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                                                                                | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                                                                                    |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                                                                                     | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                        |                   |                                                             |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam (30 minutes) or development and documentation of a computer/software program |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                        |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                        |                   |                                                             |
| <div>- Calculation and design of DC-networks</div> <div>- Operation of DC-networks</div> <div>- Fault detection and localization</div> <div>- Plant engineering</div> <div>- Components for power generation, distribution and storage</div> <div>- Industrial networks, isolated networks, on-board networks</div>                                                                                                                                                              |                                                                                        |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                        |                   |                                                             |
| After successful completion of the module, students will have a basic knowledge of the structure and function of DC- systems. They are familiar with the hazards and the necessary safety measures and regulations in DC-networks. Industrial networks, data centers and on-board networks are typical applications. By means of experiments and simulations, the students learn practical knowledge.                                                                            |                                                                                        |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                        |                   |                                                             |
| HVDC Technology: An Introduction (Michael Kurrat, TU Braunschweig)<br>HVDC Grids (D. van Hertem)<br>Microgrid: Dynamics and Control (H. Bevrani)<br>Multi-terminal Direct-Current Grids (N.R. Chaudhuri)<br>Urban DC Microgrid: Intelligent Control and Power Flow Optimization<br>Fault detection and diagnosis in engineering systems<br>Fault location on power networks (M.M. Saha)<br>Elektrische Messtechnik: Analoge, digitale und computergestützte Verfahren (R. Lerch) |                                                                                        |                   |                                                             |





|                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
| HVDC Technology: An Introduction (Michael Kurrat, TU Braunschweig) HVDC Grids (D. van Hertem) Microgrid: Dynamics and Control (H. Bevrani) Multi-terminal Direct-Current Grids (N.R. Chaudhuri) Urban DC Microgrid: Intelligent Control and Power Flow Optimization Fault detection and diagnosis in engineering systems Fault location on power networks (M.M. Saha) Elektrische Messtechnik: Analoge, digitale und computergestützte Verfahren (R. Lerch)   |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
| HVDC Technology: An Introduction (Michael Kurrat, TU Braunschweig) HVDC Grids (D. van Hertem) Microgrid: Dynamics and Control (H. Bevrani) Multi-terminal Direct-Current Grids (N.R. Chaudhuri) Urban DC Microgrid: Intelligent Control and Power Flow Optimization ( Fault detection and diagnosis in engineering systems Fault location on power networks (M.M. Saha) Elektrische Messtechnik: Analoge, digitale und computergestützte Verfahren (R. Lerch) |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Design and Function of Energy Storage Systems             |                   |                                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2423530                                                   | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                           | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the summer term                                   | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                                         | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                      | 4 / 5,0                                                   | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                                                       |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                       | 56                                                        | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                           |                   |                                                             |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                               | oral examination, 30 minutes or written exam, 120 minutes |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                           |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                           |                   |                                                             |
| <div>- Charging infrastructure</div> <div>- Double layer capacitor</div> <div>- Hydrogen technology</div> <div>- Storage parameters, system design</div> <div>- Storage technologies</div> <div>- Battery storage, ageing and diagnostics, recycling</div>                                                                                                                                                                                                 |                                                           |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                           |                   |                                                             |
| After successful completion of the module, students have a basic knowledge of the structure and function of storage systems.<br>They are informed about current and future developments in storage systems and can formulate existing challenges.<br>Students learn practical skills through excursions and exercises.                                                                                                                                     |                                                           |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                           |                   |                                                             |
| Zapf, M.: Stromspeicher und Power-to-Gas im deutschen Energiesystem. Springer Vieweg, 2017<br>Sternner, M.; Stadler, I.: Energiespeicher # Bedarf, Technologien, Integration. Springer Vieweg, 2014<br>Kurzweil, P.; Dietlmeier, O. K.: Elektrochemische Speicher - Superkondensatoren, Batterien, Elektrolyse-Wasserstoff, Rechtliche Grundlagen, Springer Vieweg, 2015<br>Korthauer, R. (Hrsg.): Handbuch Lithium-Ionen-Batterien, Springer Vieweg, 2013 |                                                           |                   |                                                             |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| Zapf, M.: Stromspeicher und Power-to-Gas im deutschen Energiesystem. Springer Vieweg, 2017<br>Sternner, M.; Stadler, I.: Energiespeicher - Bedarf, Technologien, Integration. Springer Vieweg, 2014<br>Kurzweil, P.; Dietlmeier, O. K.: Elektrochemische Speicher - Superkondensatoren, Batterien, Elektrolyse-Wasserstoff, Rechtliche Grundlagen, Springer Vieweg, 2015<br>Korthauer, R. (Hrsg.): Handbuch Lithium-Ionen-Batterien, Springer Vieweg, 2013 |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Electric Power Systems Engineering                                                                         |                   |                                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2423550                                                                                                    | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                            | Language          | english                                                     |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                                                                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                                                                          | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4 / 5,0                                                                                                    | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                                                                                        |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 56                                                                                                         | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                            |                   |                                                             |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | oral examination (30 minutes) or presentation (20 minutes plus scientific talk with examination character) |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                            |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                            |                   |                                                             |
| <ul style="list-style-type: none"><li>• Discussion of power system overvoltages</li><li>• Calculation of electric fields</li><li>• Statistical analysis of ionization and breakdown phenomena</li><li>• Calculation of the breakdown of gases (SF6), liquids (insulating oil), solids, and composite materials, as well as the breakdown characteristics of long air gaps</li><li>• Description of insulation systems currently used in high-voltage engineering, including air insulation and insulators in overhead power transmission lines, gas-insulated substation (GIS) and cables, oil-paper insulation in power transformers, paper-oil insulation in high-voltage cables, and polymer insulation in cables</li><li>• Examination of contemporary practices in insulation coordination in association with the International Electrotechnical Commission (IEC) definition and the latest standards.</li></ul>                                                                                                                         |                                                                                                            |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                            |                   |                                                             |
| <p>The students have fundamental knowledge of Power Systems and special or in-depth expertise for High-Voltage Systems Engineering.</p> <p>They learn methods with the help of discipline experiments and simulations and interpret / evaluate texts and data from Power Systems.</p> <p>They are able to make scientifically sound judgments within the scope of High-Voltage and formulate research problems.</p> <p>The students are able to select an adequate level of abstraction for a given research problem and work on that level.</p> <p>They can assess the scientific value of High-Voltage research and can formulate development or application problems.</p> <p>For Power Systems Engineering they have a systematic approach characterized by the application and development of theories, models and coherent interpretations and they can use scientific theories / model concepts.</p> <p>They reflect critically on their own way of thinking, their decisions and actions and are able to think logically (recognize</p> |                                                                                                            |                   |                                                             |

fallacies and deceptions) and critically interpret scientific data (origin, completeness, relevance, etc.) and formulate a wellfounded opinion.  
 They can communicate to others in writing and orally the results of the scientific work in the given examples and behave professionally (in the sense of reliability, commitment, correctness, precise work, perseverance, independence, etc.).  
 The students work task-related and target-oriented in the learning group and deal with group-dynamic processes. They analyze social, economic or cultural consequences of new developments in High-Voltage Transmission.

#### Literature

- High Voltage Engineering Farouk A.M. Rizk, Giao N. Trinh CRC Press 2014
- High Voltage Engineering: Fundamentals - Technology - Applications Küchler, Andreas VDI-Buch 2018



#### Related courses

#### Rules for the choice of courses

#### Compulsory attendance

| Name of the course                                                                                                                                                        | SWS | Eventtype | Language |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----------|----------|
|                                                                                                                                                                           | 2,0 | Lecture   | english  |
| <b>Literature</b>                                                                                                                                                         |     |           |          |
| High Voltage Engineering Farouk A.M. Rizk, Giao N. Trinh CRC Press 2014 High Voltage Engineering: Fundamentals - Technology - Applications Küchler, Andreas VDI-Buch 2018 |     |           |          |
|                                                                                                                                                                           | 2,0 | Exercise  | english  |

| Title                                                                                                                                                                                                                                                                            | Electrical Systems and Grids                 |                   |                                                             |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                           | 2423560                                      | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                        |                                              | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                               | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                  | 1                                            | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                            | 3 / 5,0                                      | Module owner      | Prof. Dr. Bernd Engel                                       |
| Workload (h)                                                                                                                                                                                                                                                                     | 150                                          |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                             | 42                                           | Self studying (h) | 108                                                         |
| Compulsory requirements                                                                                                                                                                                                                                                          |                                              |                   |                                                             |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                     | oral exam (30 min) or written exam (120 min) |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                               |                                              |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                         |                                              |                   |                                                             |
| Line and network types<br>Equivalent circuits of the networks<br>Electrical characteristics of the equipment<br>Calculation of lines and networks<br>Network control<br>Short circuit and load flow calculation<br>Stability<br>Protective measures                              |                                              |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                          |                                              |                   |                                                             |
| After completing the module, students will be able to understand the structure and operation of electrical power supply networks from extra-high to low voltage. The basics they have learnt enable them to independently analyse networks in the event of operation and faults. |                                              |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                       |                                              |                   |                                                             |
| Elektrische Energieversorgung, K. Heuck, Vieweg Elektrische Kraftwerke und Netze, D. Oeding, Springer                                                                                                                                                                            |                                              |                   |                                                             |

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|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|  |     |          |        |
|--|-----|----------|--------|
|  | 1,0 | Exercise | german |
|  | 2,0 | Lecture  | german |

| Title                                                                                      | Numerical Methods                                                                                           |                   |                                                             |
|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                     | 2423590                                                                                                     | Module version    |                                                             |
| Shorttext                                                                                  |                                                                                                             | Language          | german                                                      |
| Frequency of offer                                                                         | only in the summer term                                                                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                            | 1                                                                                                           | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                      | 4 / 5,0                                                                                                     | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                               | 150                                                                                                         |                   |                                                             |
| Class attendance (h)                                                                       | 56                                                                                                          | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                    |                                                                                                             |                   |                                                             |
| Expected performance/<br>Type of examination                                               | written exam (120 min) or oral examination (30 min), documentation of computer programs as independent work |                   |                                                             |
| Course achievement                                                                         |                                                                                                             |                   |                                                             |
| Contents                                                                                   |                                                                                                             |                   |                                                             |
|                                                                                            |                                                                                                             |                   |                                                             |
| Objective qualification                                                                    |                                                                                                             |                   |                                                             |
|                                                                                            |                                                                                                             |                   |                                                             |
| Literature                                                                                 |                                                                                                             |                   |                                                             |
| Numerik symmetrischer Matrizen, H.R.Schwarz, Teubner Verlag Matrizen, R. Zurmühl, Springer |                                                                                                             |                   |                                                             |



|                                 |     |            |          |
|---------------------------------|-----|------------|----------|
| Related courses                 |     |            |          |
| Rules for the choice of courses |     |            |          |
|                                 |     |            |          |
| Compulsory attendance           |     |            |          |
|                                 |     |            |          |
| Name of the course              | SWS | Eventtype  | Language |
|                                 | 2,0 | Lecture    | german   |
|                                 | 2,0 | Laboratory | german   |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Innovative Energy Systems                   |                   |                                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2423600                                     | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                           | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4 / 5,0                                     | Module owner      | Prof. Dr. Bernd Engel                                       |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                         |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 56                                          | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                             |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | oral exam (30 min) or written exam (90 min) |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                             |
| 1. Development of Energy Supply and Climate Targets<br>2. Conventional Power Plants<br>3. Renewable Energies<br>4. Novel generation systems<br>5. Power-to-X and Sector Coupling (Transport, Heat)<br>6. Storage (Battery, Hydrogen)<br>7. Island Grids<br>8. Prosumer Households                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                             |
| After completing the module, students will be able to describe the conventional and sustainable provision of electrical energy as well as associated current and future developments on the basis of basic knowledge. In addition to the provision of electrical energy, students will be able to identify various approaches to sector coupling (transport, heat) and possibilities for storing energy (battery storage, hydrogen, etc.). This module enables students to explain future requirements and changes in the energy system and to list possible advantages and disadvantages. Measures and goals in the context of potential transformations (energy transition, mobility transition, etc.) can be classified and assessed in the overall context of a sustainable energy supply. |                                             |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                             |
| Quaschning, Volker: Regenerative Energiesysteme: Technologie – Berechnung – Simulation. München 2015. Hanser Verlag. Kaltschmitt, Martin: Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Berlin 2013. Springer Vieweg.<br>Heuck, Klaus; Dettmann, Klaus-Dieter; Schulz, Detlef: Elektrische Energieversorgung: Erzeugung, Übertragung und Verteilung elektrischer Energie für Studium und Praxis. Wiesbaden 2013. Springer Vieweg.                                                                                                                                                                                                                                                                                                                                    |                                             |                   |                                                             |

Schwab, Adolf J.: Elektroenergiesysteme: Erzeugung, Übertragung und Verteilung elektrischer Energie. Berlin 2015. Springer Vieweg.



|                                                                                          |            |                  |                 |
|------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                   |            |                  |                 |
|                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                             |            |                  |                 |
|                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                          | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                        |            |                  |                 |
| Die Energiefrage Bedarf und Potentiale, Nutzung, Risiken und Kosten, K. Heinloth, Vieweg |            |                  |                 |
|                                                                                          | 2,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                      | Electrical Transmission Systems Technology       |                   |                                                             |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2423420                                          | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                  | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the winter term                          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                                | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                      | 4 / 5,0                                          | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                                              |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                       | 56                                               | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                  |                   |                                                             |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                               | Written exam (120 minutes) or oral exam (30 min) |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                  |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                  |                   |                                                             |
| <ul style="list-style-type: none"><li>• High-Voltage Technologies</li><li>• Smart Grids</li><li>• High-Voltage Direct Current Transmission</li><li>• High-Temperature Superconductors</li></ul>                                                                                                                                                                                                                                            |                                                  |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                  |                   |                                                             |
| After successful completion of the course, students have a fundamental understanding of latest and future technologies that are relevant for the transmission of electrical energy. They are informed about current and future developments regarding transmission grids and are able to formulate existing challenges. Students are also able to analyze, assess and design technologies, components, and systems on a fundamental level. |                                                  |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                  |                   |                                                             |
| Hochspannungstechnik, A. Küchler, Springer Verlag<br>Elektroenergiesysteme, A. Schwab, Springerverlag<br>Elektrische Energieversorgung, K. Heuck, Vieweg<br>Grundkurs Leistungselektronik, J. Specovius, Vieweg+Teubner Verlag<br>Supraleitung, W. Buckel, VCH                                                                                                                                                                             |                                                  |                   |                                                             |

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|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
| Bachelor's module                      |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Exercise         | german          |
|                                        | 2,0        | Lecture          | german          |

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|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------|-------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | electrotechnical laboratory practical course specialization battery technologies |                   |                                                             |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2423000000                                                                       | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                  | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | only in the winter term                                                          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1                                                                                | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 4 / 5,0                                                                          | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 150                                                                              |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 42                                                                               | Self studying (h) | 108                                                         |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                  |                   |                                                             |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | For the seminar: portfolio in addition to passed lab work                        |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Lab work: successful participation in four lab experiments incl. written report  |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                  |                   |                                                             |
| <p>Practical experiments in the areas of:</p> <ul style="list-style-type: none"><li>• Formation and post-mortem analysis</li><li>• Electrochemical characterizations</li><li>• Pressure analysis</li><li>• Simulation and modeling</li></ul> <p>The practical experiments include preparation, experimental work, colloquium and written elaboration. This knowledge will be deepened during the seminar.</p>                                                                                                                                                                                                                                                                                                         |                                                                                  |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                  |                   |                                                             |
| Students know and understand in-depth methods of battery technology, including the characterization, analysis and simulation of batteries. Students will be able to apply the basic knowledge they have already acquired in other modules, e.g. the structure and function of storage systems. They have the ability to collect, document and evaluate experimental data from various battery test cells and to cooperate successfully with fellow students. Students are able to make scientifically sound judgments in the context of battery technologies. Draw new conclusions from their own results and the state of knowledge in the literature. This scientific work must be presented orally and in writing. |                                                                                  |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                  |                   |                                                             |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                  |                   |                                                             |

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|-----------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                        |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                        |            |                  |                 |
|                                                                                               |            |                  |                 |
| <b>Compulsory attendance</b>                                                                  |            |                  |                 |
|                                                                                               |            |                  |                 |
| <b>Name of the course</b>                                                                     | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| seminar - electrotechnical laboratory practical course specialization battery technologies    | 2,0        | Seminar          | german          |
| laboratory - electrotechnical laboratory practical course specialization battery technologies | 2,0        | Laboratory       | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Electrical Distribution Systems Technology |                   |                                                             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2423300                                    | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                            | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the summer term                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                          | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 4 / 5,0                                    | Module owner      | Prof. Dr. Bernd Engel                                       |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                        |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 56                                         | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                            |                   |                                                             |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Written exam (120 min)                     |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                            |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                            |                   |                                                             |
| <ul style="list-style-type: none"><li>• Electrical Grid and Grid structures</li><li>• Basic terms, energy history, future</li><li>• Cable and overhead line</li><li>• Transformer</li><li>• Substations and Control rooms</li><li>• Grid safety &amp; security</li><li>• Grid planning, calculation and AI</li><li>• Grid financing and grid fees</li><li>• Innovative grid operation using the example of medium and low voltage grids</li><li>• Active power management in distribution grids</li></ul> |                                            |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                            |                   |                                                             |
| After successfully completing the module, students will have basic knowledge of technologies that are relevant to the distribution of electrical energy now and in the future. They are informed about current and future developments in electrical energy distribution networks and can formulate existing challenges. They are able to analyse and assess technologies, components and systems and to design and dimension them in principle.                                                          |                                            |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                            |                   |                                                             |
| Elektrische Energieverteilung – Flosdorff, Hilgarth – Vieweg + Teubner<br>Elektrische Energieversorgung – Heuck, Dettmann, Schulz – SpringerVieweg<br>Taschenbuch der elektrischen Energietechnik – Schufft – Hanser<br>Elektrische Anlagentechnik – Knies, Schierack – Hanser<br>Elektroenergiesysteme – Schwab – Springer                                                                                                                                                                               |                                            |                   |                                                             |



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| <b>Related courses</b>                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                   | 3,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| Elektrische Energieverteilung; Flosdorff, Hilgarth; Vieweg + Teubner<br>Elektrische Energieversorgung; Heuck, Dettmann, Schulz; SpringerVieweg<br>Taschenbuch der elektrischen Energietechnik; Schufft; Hanser<br>Elektrische Anlagentechnik; Knies, Schierack; Hanser<br>Elektroenergiesysteme; Schwab; Springer |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                   | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| Elektrische Energieverteilung; Flosdorff, Hilgarth; Vieweg + Teubner<br>Elektrische Energieversorgung; Heuck, Dettmann, Schulz; SpringerVieweg<br>Taschenbuch der elektrischen Energietechnik; Schufft; Hanser<br>Elektrische Anlagentechnik; Knies, Schierack; Hanser<br>Elektroenergiesysteme; Schwab; Springer |            |                  |                 |



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| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Introduction to power grid technology |                   |                                                             |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2423000020                            | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                       | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the winter term               | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                     | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4 / 5,0                               | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                   |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 70                                    | Self studying (h) | 80                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                       |                   |                                                             |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Oral exam 30 min.                     |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                       |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                       |                   |                                                             |
| <ul style="list-style-type: none"><li>• Nodes in the network, all voltage levels</li><li>• Basics of networks: Grounding system, Error types</li><li>• Isolation Coordination</li><li>• Thermal and mechanical stress</li><li>• Protection Systems</li><li>• Switching operations: Component network interface</li><li>• Switches: AC and DC extinguishing principle</li><li>• Fundamentals of Plasma Technology</li><li>• Vacuum switch</li><li>• Gas switch</li><li>• DC Voltage Switches</li><li>• Transformer</li><li>• Structure of switchgear and basic circuits used</li></ul>                                        |                                       |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                       |                   |                                                             |
| After successful completion of the module, students will have knowledge of key technologies, structure and function of future power grids. They are able to understand their complex interaction and derive requirements for components in order to ensure the operation and protection of the power grids in a wide variety of system states. In addition, they are able to apply the knowledge imparted in the design of switches at all voltage levels for direct and alternating current of the power grids. On the basis of excursions and exercises, the knowledge is applied and insights into practice are provided. |                                       |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                       |                   |                                                             |
| Adil Erk und Martin Schmelzle. Grundlagen der Schaltgerätetechnik: Kontaktglieder und Löscheinrichtungen elektrischer Schaltgeräte der Energietechnik. Berlin: Springer, 1974. ISBN: 3-540-06075-8                                                                                                                                                                                                                                                                                                                                                                                                                           |                                       |                   |                                                             |
| W. Rieder. Plasma und Lichtbogen. Braunschweig: Friedr. Vieweg & Sohn GmbH, 1967                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                       |                   |                                                             |
| Josef Lutz. Halbleiter-Leistungsbaulemente: Physik, Eigenschaften, Zuverlässigkeit. 2. Aufl. Berlin and Heidelberg: Springer Vieweg, 2012. ISBN: 978-3-642-29795-3                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                       |                   |                                                             |

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| <p>Andreas Küchler. Hochspannungstechnik: Grundlagen - Technologie -Anwendungen. 3., neu bearbeitete und erweiterte Auflage. VDI-Buch. Heidelberg et al.: Springer, 2009. ISBN: 978- 3-540-78412-8</p> <p>Stefan Kopatsch und Gerald Kopatsch. ABB Schaltanlagen-Handbuch 13. Auflage. Wurth und Körner, Werbung und Design, 68163 Mannheim</p> |
| <b>Remark</b>                                                                                                                                                                                                                                                                                                                                   |
| This module replaces "Elektrische Energieanlagen 2/Betriebsmittel" ("Electrical Power Systems 2").                                                                                                                                                                                                                                              |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
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| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Introduction to power grid technology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <p>Adil Erk und Martin Schmelzle. Grundlagen der Schaltgerätetechnik: Kontaktglieder und Löscheinrichtungen elektrischer Schaltgeräte der Energietechnik. Berlin: Springer, 1974. ISBN: 3-540-06075-8</p> <p>W. Rieder. Plasma und Lichtbogen. Braunschweig: Friedr. Vieweg &amp; Sohn GmbH, 1967</p> <p>Josef Lutz. Halbleiter-Leistungsbaulemente: Physik, Eigenschaften, Zuverlässigkeit. 2. Aufl. Berlin and Heidelberg: Springer Vieweg, 2012. ISBN: 978-3-642-29795-3</p> <p>Andreas Küchler. Hochspannungstechnik: Grundlagen - Technologie -Anwendungen. 3., neu bearbeitete und erweiterte Auflage. VDI-Buch. Heidelberg et al.: Springer, 2009. ISBN: 978- 3-540-78412-8</p> <p>Stefan Kopatsch und Gerald Kopatsch. ABB Schaltanlagen-Handbuch 13. Auflage. Wurth und Körner, Werbung und Design, 68163 Mannheim</p> |            |                  |                 |
| Introduction to power grid technology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <p>Adil Erk und Martin Schmelzle. Grundlagen der Schaltgerätetechnik: Kontaktglieder und Löscheinrichtungen elektrischer Schaltgeräte der Energietechnik. Berlin: Springer, 1974. ISBN: 3-540-06075-8</p> <p>W. Rieder. Plasma und Lichtbogen. Braunschweig: Friedr. Vieweg &amp; Sohn GmbH, 1967</p> <p>Josef Lutz. Halbleiter-Leistungsbaulemente: Physik, Eigenschaften, Zuverlässigkeit. 2. Aufl. Berlin and Heidelberg: Springer Vieweg, 2012. ISBN: 978-3-642-29795-3</p> <p>Andreas Küchler. Hochspannungstechnik: Grundlagen - Technologie -Anwendungen. 3., neu bearbeitete und erweiterte Auflage. VDI-Buch. Heidelberg et al.: Springer, 2009. ISBN: 978- 3-540-78412-8</p> <p>Stefan Kopatsch und Gerald Kopatsch. ABB Schaltanlagen-Handbuch 13. Auflage. Wurth und Körner, Werbung und Design, 68163 Mannheim</p> |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                |                                            |                   |                                                             |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|-------------------|-------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                          | High-Voltage Test- and Measurement Systems |                   |                                                             |
| Number                                                                                                                                                                                                                                                                                                                         | 2423000030                                 | Module version    |                                                             |
| Shorttext                                                                                                                                                                                                                                                                                                                      |                                            | Language          | german                                                      |
| Frequency of offer                                                                                                                                                                                                                                                                                                             | only in the summer term                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                                                                                                                                                                                                                                                                | 1                                          | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                          | 4 / 5,0                                    | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                   | 150                                        |                   |                                                             |
| Class attendance (h)                                                                                                                                                                                                                                                                                                           | 56                                         | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                        |                                            |                   |                                                             |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                      | Design project                             |                   |                                                             |
| Course achievement                                                                                                                                                                                                                                                                                                             |                                            |                   |                                                             |
| Contents                                                                                                                                                                                                                                                                                                                       |                                            |                   |                                                             |
| <ul style="list-style-type: none"><li>• Design of High-Voltage Components</li><li>• Test Philosophy and Design of Test</li><li>• Concepts for High-Voltage Test Facilities</li><li>• High-Voltage Generation</li><li>• High-Voltage Measurement</li><li>• High-Current Generation</li><li>• High Current Measurement</li></ul> |                                            |                   |                                                             |
| Objective qualification                                                                                                                                                                                                                                                                                                        |                                            |                   |                                                             |
| <ul style="list-style-type: none"><li>• Fundamental Knowledge of High-Voltage and High-Current Tests</li><li>• Fundamental Analysis of High-Voltage and High-Current Test and Measurement Circuits</li><li>• Quality Assessment, Evaluation and Documentation of Test Performance for High-Voltage Component</li></ul>         |                                            |                   |                                                             |
| Literature                                                                                                                                                                                                                                                                                                                     |                                            |                   |                                                             |
| Test and Measuring Techniques, Wolfgang Hauschild, Eberhard Lemke, Springer, 2014                                                                                                                                                                                                                                              |                                            |                   |                                                             |
| Remark                                                                                                                                                                                                                                                                                                                         |                                            |                   |                                                             |
| This module complies with "High-Voltage Test- and Measurement Systems" (2423570). You can choose only one of these modules.                                                                                                                                                                                                    |                                            |                   |                                                             |



|                                                                                                                             |            |                  |                 |
|-----------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                      |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                      |            |                  |                 |
| This module complies with "High-Voltage Test- and Measurement Systems" (2423570). You can choose only one of these modules. |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                |            |                  |                 |
|                                                                                                                             |            |                  |                 |
| <b>Name of the course</b>                                                                                                   | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| High-Voltage Test- and Measurement Systems                                                                                  | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                           |            |                  |                 |
| Test and Measuring Techniques, Wolfgang Hauschild, Eberhard Lemke, Springer, 2014                                           |            |                  |                 |
| High-Voltage Test- and Measurement Systems                                                                                  | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                           |            |                  |                 |
| Test and Measuring Techniques, Wolfgang Hauschild, Eberhard Lemke, Springer, 2014                                           |            |                  |                 |

**Major Specialisation: Photonics and Quantum Technologies - Compulsory Elective Modules**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                           |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Nano- and Bioelectronic System                                                            |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2413560                                                                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                           | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | only in the winter term                                                                   | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                                                                         | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 3 / 5,0                                                                                   | Module owner      | Prof. Dr. Tobias Voß                                     |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 150                                                                                       |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 42                                                                                        | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                           |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Oral exam (30 minutes) or written exam (120 minutes), depending on number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                           |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                           |                   |                                                          |
| Introduction to nanotechnology<br>growth, nanostructuring and characterization processes and tools (lithography, microscopy, raster probe technique, spectroscopy, nanotubes, nanowires, nanoparticles, hybrid nanostructures<br>bio-organic functionalization of surfaces (Langmuir-Blodgett, self-assembled monolayers on metals and semiconductors)<br>semiconductor nano- and biosensors based on different inorganic and organic nanomaterials<br>hybrid nanostructures for optoelectronics  |                                                                                           |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                           |                   |                                                          |
| After completion of the module Nano- and Bioelectronic Systems, the students possess<br>- a basic understanding of the most important techniques for the preparation and characterization of inorganic and hybrid nanoelectronic systems (nanoparticles, nanotubes, nanowires, quantum well structures)<br>- the ability to combine acquired fundamental knowledge to understand and evaluate advanced semiconductor-based nano and biosensors as well as nanoscale hybrid optoelectronic devices |                                                                                           |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                           |                   |                                                          |
| "Nanoelectronics and Information Technology. Advanced Electronic Materials and Novel Devices", R. Waser (Ed.), Wiley-VCH, 2nd Ed. (2005): ISBN-13: 978-3527405428<br>"Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer, 2nd. Ed. (2006): ISBN-13: 978-3540298557                                                                                                                                                                                                                  |                                                                                           |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                           |                   |                                                          |
| primarily master module                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                           |                   |                                                          |



|                                                                                                                                                                                                          |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                          | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                        |            |                  |                 |
| "Nanoelectronics and Information Technology. Advanced Electronic Materials and Novel Devices", R. Waser (Ed.), Wiley-VCH (2003) "Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer (2004) |            |                  |                 |
|                                                                                                                                                                                                          | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                        |            |                  |                 |
| "Nanoelectronics and Information Technology. Advanced Electronic Materials and Novel Devices", R. Waser (Ed.), Wiley-VCH (2003) "Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer (2004) |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Optoelectronics                                             |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2415290                                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the summer term                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                                           | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                                                     | Module owner      | Prof. Dr. Wolfgang Kowalsky                              |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Written exam (90 min) or oral exam (30 min) or presentation |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                             |                   |                                                          |
| <div>- Propagation of electromagnetic waves in free space and in guiding structures</div> <div>- Refraction, reflexion, total reflexion at dielectric interfaces</div> <div>- Optical guiding in film and strip waveguides, mechanisms of losses</div> <div>- Optical modes and theoretical description</div> <div>- field distribution in step and gradient profiles, analogy to quantum mechanics</div> <div>- Periodic structures to distributed feedback: DFB, DBR</div> <div>- Electrooptical interaction, directional couplers</div> |                                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                             |                   |                                                          |
| After completion of the module students have gained knowledge in the functional mechanisms and the design of devices for integrated optics, particularly of waveguides. They are able to apply these competences in the analysis of optoelectronic systems with regard to device and circuit level and to qualify and optimize these systems.                                                                                                                                                                                              |                                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                             |                   |                                                          |
| K. J. Ebeling, Integrierte Optoelektronik, Springer, ISBN 3540546553                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                             |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|  |     |          |        |
|--|-----|----------|--------|
|  | 2,0 | Lecture  | german |
|  | 1,0 | Exercise | german |



|                                                                                                                                                                                                                                                                                                                                                                |                                                    |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                          | Nonlinear Photonics                                |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                         | 2415470                                            | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                      |                                                    | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                             | only in the winter term                            | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                | 1                                                  | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                          | 4 / 5,0                                            | Module owner      | Prof. Dr. Thomas Schneider                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                   | 150                                                |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                           | 56                                                 | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                        |                                                    |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                      | Written exam, 90 minutes, or oral exam, 30 minutes |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                             |                                                    |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                       |                                                    |                   |                                                          |
| <div>- Basics of linear optics</div> <div>- 2nd order nonlinear optical effects</div> <div>- 3rd order nonlinear optical effects</div> <div>- Nonlinear scattering</div> <div>- Optical telecommunications</div> <div>- Nonlinear effects in optical fibers</div> <div>- Suppression of nonlinear effects</div> <div>- Applications of nonlinear effects</div> |                                                    |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                        |                                                    |                   |                                                          |
| After a successful participation, the students know the main basics of nonlinear photonics and will be able to use them for the evaluation of optical systems and optical data transmission systems.                                                                                                                                                           |                                                    |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                     |                                                    |                   |                                                          |
| T. Schneider "#Nonlinear Optics in Telecommunications#", Springer Verlag                                                                                                                                                                                                                                                                                       |                                                    |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

|                     |     |          |         |
|---------------------|-----|----------|---------|
| Nonlinear Photonics | 2,0 | Lecture  | english |
| Nonlinear Photonics | 2,0 | Exercise | english |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Analog Integrated Circuits |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2420150                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                          | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                    | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                         | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam 30 min           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                   |                                                          |
| <p>All modern mobile radio applications (e.g. GSM, WLAN, GPS, Bluetooth, Dect. etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are increasingly being integrated in low-cost CMOS technology, which results in significant differences to the classic design of high-frequency circuits based on discrete components. The lecture gives an introduction to the design of analog, integrated CMOS mobile radio receiver circuits.</p> <p>The lecture is divided into the following chapters:</p> <ul style="list-style-type: none"><li>- High frequency amplifier circuits</li><li>- Simulation of electronic noise</li><li>- Low-noise input amplifiers in CMOS</li><li>- Mixer circuits</li><li>- Phase-locked loops (PLLs)</li><li>- Voltage-controlled oscillators</li></ul> |                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| <p>After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                   |                                                          |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits" Cambridge University Press                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |

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| <b>Related courses</b>                            |            |                  |                 |
|---------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>            |            |                  |                 |
| Prerequisite for this module: Circuit Design (ST) |            |                  |                 |
| <b>Compulsory attendance</b>                      |            |                  |                 |
|                                                   |            |                  |                 |
| <b>Name of the course</b>                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Analog Integrated Circuits (2013)                 | 1,0        | Exercise         | english         |
| Analog Integrated Circuits (2013)                 | 2,0        | Lecture          | english         |

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|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Gallium Nitride Technology                  |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2413000030                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                     | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| <p>The course builds on ‘Lighting Technology I’. While Lighting Technology I focusses on general questions of lighting and lighting technology, this course discusses LED technology and gallium nitride technology in particular:</p> <ul style="list-style-type: none"><li>• Physical principles of LEDs. Band gap engineering in LEDs.</li><li>• Semiconductor materials for optoelectronics</li><li>• Relationship between material properties and LED properties</li><li>• Manufacturing processes</li><li>• Efficiency considerations</li><li>• Front-end and back-end processing</li><li>• Application examples in general lighting, automotive technology, sensor technology</li><li>• Infrared LEDs, visible light, UV LEDs</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| <p>After completing the module, students will have an overview of the current state of LED technology and the development opportunities that solid state lighting will offer in the future. In addition, they will have a basic understanding of the physical processes within LEDs.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |

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|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Gallium Nitride Technology             | 2,0        | Lecture          | german          |
| Gallium Nitride Technology             | 1,0        | Exercise         | german          |

**Major Specialisation: Photonics and Quantum Technologies - Elective Modules**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Fundamentals of Nano Optics                  |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1520430                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                            | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                      | Module owner      | Prof. Dr. Stefanie Kroker                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| 1. Basic concepts (photonic crystals, plasmonics)<br>2. Production and characterisation (metrology) of nano structures<br>3. Photonic nano materials / meta materials / meta surfaces<br>4. Optic nano emitters and nano antennae<br>5. Active photonic elements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| The participants can describe basic phenomena of light propagation (reflection, scattering, absorption, transmission) at interfaces and in homogeneous media qualitatively and quantitatively.<br>Participants can name important basic elements of nanooptics, such as waveguides, optical gratings, photonic crystals or metamaterials, discuss their properties qualitatively and name fields of application.<br>Participants are able to identify the basic elements in complex optical systems and describe their respective functions.<br>The participants can name important processes of micro- and nanostructuring and explain how they work.<br>The participants can solve the wave equation in simple dielectric, metallic and hybrid nanooptical systems analytically and semi-analytically and interpret the solutions.<br>Participants can classify optical resonance phenomena in nanooptical systems and name their essential properties. |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                              |                   |                                                          |
| Novotny, Hecht: Principles of nano-optics, Cambridge University Press 2016<br>Prasad: Nanophotonics, John Wiley & Sons 2004<br>Jahns, Helfert: Introduction to Micro- and Nanooptics, Wiley VCH 2012                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Fundamentals of Nano Optics            | 2,0        | Lecture          | english         |
| Fundamentals of Nano Optics            | 1,0        | Exercise         | english         |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                   |                   |                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Nanoelectronics                                                                   |                   |                                                                        |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2411200                                                                           | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                   | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the summer term                                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                                                 | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4 / 5,0                                                                           | Module owner      | Prof. Dr. Oleksandr Dobrovolskiy                                       |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                                                               |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 56                                                                                | Self studying (h) | 94                                                                     |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                   |                   |                                                                        |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Oral exam (30 min), written exam (120 min) only for a high number of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                   |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                   |                   |                                                                        |
| <ul style="list-style-type: none"><li>• Quantum mechanics Wave function, potentials, interaction</li><li>• Magnetism</li><li>• Superconductivity</li><li>• Manufacturing processes</li><li>• Josephson junctions</li><li>• SET components</li><li>• Data memory</li><li>• THz transistors</li><li>• Quantum computing</li></ul>                                                                                                                                                                                                                                                                                                                                                |                                                                                   |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                   |                   |                                                                        |
| After completing the module 'Nanoelectronics', students will have an overview of the fundamentals of quantum mechanics and its application to metallic, magnetic and superconducting components with nanometre dimensions.                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                   |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                   |                   |                                                                        |
| A multi-media CD ROM with script and exercises is available for the lecture<br>- R. Waser, #Nanoelectronics and Information Technology#, Wiley-VCH, 2003, ISBN 978-3527403639<br>- M. Köhler, #Nanotechnologie#, Wiley-VCH, 2007, ISBN 978-3527318711<br>- Jasprit Singh, #Modern Physics for Engineers#, Wiley, 1999, ISBN 978-0471330448<br>- N. Ashcroft, N. Mermin, #Solid State Physics#, Cengage Learning Services, 1976, ISBN 978-0030839931<br>- S. Flügge, #Rechenmethoden der Quantentheorie#, Springer Verlag 1993, ISBN 978-3540567769<br>- W. Nolting, #Quantenmechanik#, Band 5 aus #Grundkurs: Theoretische Physik#, Springer-Verlag, 2007, ISBN 978-3540688686 |                                                                                   |                   |                                                                        |



|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Nanoelectronics                                                                                                                                                                                                                                                                                                                                                                                                                     | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <ul style="list-style-type: none"> <li>• R. Waser, Nanoelectronics and Information Technology, Wiley-VCH</li> <li>• M. Köhler, Nanotechnologie, Wiley-VCH</li> <li>• Jasprit Singh, Modern Physics for Engineers, Wiley</li> <li>• N. Ashcroft, N. Mermin, Solid State Physics</li> <li>• S. Flügge, Rechenmethoden der Quantentheorie</li> <li>• W. Nolting, Quantenmechanik, Band 5 aus Grundkurs: Theoretische Physik</li> </ul> |            |                  |                 |
| Nanoelectronics                                                                                                                                                                                                                                                                                                                                                                                                                     | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <ul style="list-style-type: none"> <li>• R. Waser, Nanoelectronics and Information Technology, Wiley-VCH</li> <li>• M. Köhler, Nanotechnologie, Wiley-VCH</li> <li>• Jasprit Singh, Modern Physics for Engineers, Wiley</li> <li>• N. Ashcroft, N. Mermin, Solid State Physics</li> <li>• S. Flügge, Rechenmethoden der Quantentheorie</li> <li>• W. Nolting, Quantenmechanik, Band 5 aus Grundkurs: Theoretische Physik</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Integrated Circuits     |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2413280                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                         | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | only in the winter term | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1                       | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 3 / 5,0                 | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 150                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 42                      | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                         |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | oral exam (20 min)      |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                         |                   |                                                          |
| <p>The module provides an overview of the operation, design, and technology of integrated electronic circuits in microelectronics.</p> <ul style="list-style-type: none"><li>• Introduction</li><li>• Basic digital circuits</li><li>• MOS and CMOS</li><li>• Silicon wafer manufacturing</li><li>• MOSFET process technology</li><li>• Nanolithography</li><li>• Etching techniques and oxidation</li><li>• Design automation, design rules, and assembly techniques</li><li>• Back-end technologies</li><li>• Modern developments: Memory technologies</li></ul> |                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                         |                   |                                                          |
| <p>After completing the module, students will be able to understand integrated circuits, their structure and mode of operation and design simple integrated circuits themselves. A further focus is on the methods of nanotechnology.</p>                                                                                                                                                                                                                                                                                                                          |                         |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                         |                   |                                                          |
| <p>Lecture slides and short script<br/>J.M.Rabaey, A.Chandrakasan, B. Nikolic, Digital Integrated Circuits<br/>Prentice Hall Electronics and VLSI Series, 2002 ISBN: 8120322576<br/>A. Schlachetzki, Integrierte Schaltungen, Teubner, 1978, (as copy at IHT) ISBN: 3-519-03070-5<br/>D. Widmann, H. Mader, H. Friedrich, Technologie Hochintegrierte Schaltungen, Springer,1996<br/>ISBN:3540593578<br/>W. Prost, Technologie der III/V Halbleiter, Springer, 1997 ISBN: 3540628045</p>                                                                           |                         |                   |                                                          |



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|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2,0        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <p>Vorlesungsfolien und Kurzschrift</p> <p>K.-H. Cordes, A. Waag, N. Heuck: Integrierte Schaltungen; Pearson Studium, 2010</p> <p>J.M.Rabaey, A.Chandrakasan, B. Nikolic, Digital Integrated Circuits Prentice Hall Electronics and VLSI Series, 2003, 1996</p> <p>A. Schlachetzki, Integrierte Schaltungen, Teubner, 1978, (als Kopie im IHT)</p> <p>D. Widmann, H. Mader, H. Friedrich, Technologie Hochintegrierte Schaltungen, Springer, 1996</p> <p>W. Prost, Technologie der III/V-Halbleiter, Springer, 1997</p> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1,0        | Exercise         | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| K.-H. Cordes, A. Waag, N. Heuck : Integrierte Schaltungen; Pearson Studium, 2010                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |

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|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Solar Cells                            |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2413310                                | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                        | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | every 2 years in the winter term       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                                      | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 3 / 5,0                                | Module owner      | Prof. Dr. Stefanie Kroker                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                                    |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 42                                     | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                        |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Oral exam (30 min) or <i>Klausur</i> + |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                        |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                        |                   |                                                          |
| <p>The module proves an overview on photovoltaic generation of energy with its physical basics to fabrication of solarcells and application in modules and solar plants.</p> <ul style="list-style-type: none"><li>• Politics of renewable energies</li><li>• Physical basics of photovoltaic generation of electricity (sun radiation, absorption of radiation by semi-conductors, p-n-junction, I-U-characteristics)</li><li>• Fabrication and structure of monocrystalline and multi-crystalline Solar cells</li><li>• Thin film solar cells, organic cells, dye cells</li><li>• Comparison of the different solar cell concepts</li><li>• Dimensioning of solar plants</li><li>• Applications</li></ul> |                                        |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                        |                   |                                                          |
| <p>The students can describe the principles of photovoltaic generation of electricity in solar cells. They can characterize solar cells to optimize their efficiency and configure simple photovoltaic devices using their characteristic parameters and geographic factors.</p>                                                                                                                                                                                                                                                                                                                                                                                                                            |                                        |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                        |                   |                                                          |
| <ul style="list-style-type: none"><li>• Lecture slides and short script</li><li>• H.-G. Wagemann, A. Schmidt: Grundl. d. optoelektron. Halbleiterbauelemente; Teubner Stuttgart 1998 ISBN: 3-519-03240-6</li><li>• H.-G. Wagemann, H. Eschrich: Grundl. d. photovoltaischen Energieumwandlung; Teubner Stuttgart 1994 ISBN: 3-519-03218-X</li></ul>                                                                                                                                                                                                                                                                                                                                                         |                                        |                   |                                                          |

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|--------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                               |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                               |            |                  |                 |
|                                                                                                                                      |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                         |            |                  |                 |
|                                                                                                                                      |            |                  |                 |
| <b>Name of the course</b>                                                                                                            | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                      | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                    |            |                  |                 |
| Vorlesungsfolien H.-G. Wagemann, H. Eschrich: Grundlagen der photovoltaischen Energiewandlung; Teubner Studienbücher, Stuttgart 1994 |            |                  |                 |
|                                                                                                                                      | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Semiconductor Metrology |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2413330                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                         | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the summer term | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                       | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 3 / 5,0                 | Module owner      | Prof. Dr. Erwin Peiner                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 42                      | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                         |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | oral exam (30 min)      |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |                   |                                                          |
| <ul style="list-style-type: none"><li>- Crystal-structure analysis, X-ray diffraction</li><li>- Lattice defects</li><li>- Epitaxial layers, nanostructures, lattice mismatch</li><li>- Microscopy (light, electrons, scanning probes), imaging modes, analytical electron microscopy</li><li>- Band structure, band gap, excitation spectroscopy, spatially resolved luminescence, effective mass</li><li>- Electrical transport properties, piezoresistive effect</li><li>- Charge carrier concentration and mobility, Hall method, CV method</li><li>- Optical absorption, Fourier transform spectroscopy</li><li>- Impurities and defects, chemical analysis, deep traps</li><li>- Minority carrier lifetime, diffusion length</li><li>- Metal-semiconductor junction, Schottky contact, Ohmic contact, sheet resistance</li><li>- Oxide layers, ellipsometry</li><li>- Device characteristics</li></ul> |                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                         |                   |                                                          |
| After completing the module semiconductor characterization, the students will have <ul style="list-style-type: none"><li>- a basic understanding of the most important methods for characterizing semiconductor materials</li><li>- the ability to select appropriate quality control procedures in the manufacture of semiconductor devices</li><li>- in-depth knowledge and practical experience in the analysis and evaluation of measurement results with bulk crystals, layers as well as micro- and nanostructured devices</li></ul>                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |
| K. Kopitzki: Einführung in die Festkörperphysik (Teubner, Stuttgart, 1989) ISBN: 3-519-13083-1<br>H. Alexander: Physikalische Grundlagen der Elektronenmikroskopie (Teubner, Stuttgart, 1997) ISBN: 3-519-03221-X<br>W. Prost: Technologie der III/V-Halbleiter: III/V-Heterostrukturen und elektronische Höchstfrequenz-Bauelemente (Springer, Berlin, 1997) ISBN:3-540-62804-5<br>W. Schäfer, G. Terlecki: Halbleiterprüfung (Hüthig, Heidelberg, 1986) ISBN: 3-778-51007-X                                                                                                                                                                                                                                                                                                                                                                                                                               |                         |                   |                                                          |

D. K. Schroder: Semiconductor Material and Device Characterization (Wiley, New York, 1990) ISBN: 0-471-51104-8  
 R. Wiesendanger (Hrsg): Scanning Probe Microscopy - Analytical Methods (Springer, Berlin, 1998) ISBN: 3-540-63815-6  
 Script and exercise materials will be handed out.



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| K. Kopitzki: Einführung in die Festkörperphysik (Teubner, Stuttgart, 1989)<br>H. Alexander: Physikalische Grundlagen der Elektronenmikroskopie (Teubner, Stuttgart, 1997)<br>W. Prost: Technologie der III/V-Halbleiter: III/V-Heterostrukturen und elektronische Höchstfrequenz-Bauelemente (Springer, Berlin, 1997)<br>W. Schäfer, G. Terlecki: Halbleiterprüfung (Hüthig, Heidelberg, 1986)<br>D. K. Schroder: Semiconductor Material and Device Characterization (Wiley, New York, 1990)<br>R. Wiesendanger (Hrsg): Scanning Probe Microscopy - Analytical Methods (Springer, Berlin, 1998) |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| Übungsunterlagen und Vorlesungsskript werden verteilt.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Packaging and Interconnection Technology |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2413390                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                          | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | only in the summer term                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                        | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 3 / 5,0                                  | Module owner      | Prof. Dr. Erwin Peiner                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 150                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 42                                       | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                          |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | oral exam (30 min)                       |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                          |                   |                                                          |
| <ul style="list-style-type: none"><li>- Open wiring, bread board, printed circuit board</li><li>- Thick film technologies, substrates, screen printing and pastes, thin film technology, photolithography</li><li>- Surface mount technology, components, housing forms, modern developments (TAB, BGA, flip chip, CSP, MCM)</li><li>- Power modules, special requirements</li><li>- Cooling, basics and problems, air cooling, liquid cooling</li><li>- Thermomechanical stresses and reliability, basics, examples</li><li>- Soldering</li><li>- Adhesive bonding</li><li>- Wire bonding</li><li>- Direct copper bonding</li><li>- Low-temperature joining technology</li></ul> |                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                          |                   |                                                          |
| <p>After completing the module electronic packaging, the students will have</p> <ul style="list-style-type: none"><li>- a basic understanding of the most important processes for assembling and joining electronic devices and components</li><li>- the ability to select suitable processes for packaging in the manufacture of semiconductor modules</li><li>- in-depth knowledge and practical experience in the use, analysis and evaluation of methods of electronic packaging</li></ul>                                                                                                                                                                                    |                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                          |                   |                                                          |
| <p>W. Scheel (Hrsg.): Baugruppenteknologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) ISBN: 3-341-01100-5</p> <p>H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik # Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01097-1</p> <p>H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik # Hybridträger (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01099-8</p> <p>M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiesbaden, 1991) ISBN: 3-528-06392-0</p>                                                                                                                                     |                                          |                   |                                                          |

J. H. Lau, "Recent Advances and Trends in Advanced Packaging," in IEEE Transactions on Components, Packaging and Manufacturing Technology, vol. 12, no. 2, pp. 228-252, Feb. 2022, doi: 10.1109/TCPMT.2022.3144461.

Y. Yang, L. Dorn-Gomba, R. Rodriguez, C. Mak and A. Emadi, "Automotive Power Module Packaging: Current Status and Future Trends," in IEEE Access, vol. 8, pp. 160126-160144, 2020, doi: 10.1109/ACCESS.2020.3019775.

Morris J.E. (2018) Nanopackaging: Nanotechnologies and Electronics Packaging. In: Morris J. (eds) Nanopackaging. Springer, Cham. [https://doi.org/10.1007/978-3-319-90362-0\\_1](https://doi.org/10.1007/978-3-319-90362-0_1)



|                                                                                                                                 |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                          |            |                  |                 |
|                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                    |            |                  |                 |
|                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                 | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                               |            |                  |                 |
| Unterlagen werden verteilt.                                                                                                     |            |                  |                 |
|                                                                                                                                 | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                               |            |                  |                 |
| W. Scheel (Hrsg.): Baugruppenteknologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) |            |                  |                 |
| H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik - Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994)                |            |                  |                 |
| H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik - Hybridträger (Verlag Technik, Berlin, Saulgau, 1994)                 |            |                  |                 |
| M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiesbaden, 1991)                                                                |            |                  |                 |

| Title                                                                                                                                                                                 | Special Problems in Semiconductor Nano Technology                                 |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                | 2413400                                                                           | Module version    |                                                          |
| Shorttext                                                                                                                                                                             |                                                                                   | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                    | every term                                                                        | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                       | 1                                                                                 | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                 | 3 / 5,0                                                                           | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                          | 150                                                                               |                   |                                                          |
| Class attendance (h)                                                                                                                                                                  | 42                                                                                | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                               |                                                                                   |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                             | Presentation (APO § 9 Abs. 7) on a special topic in Semiconductor Nano Technology |                   |                                                          |
| Course achievement                                                                                                                                                                    |                                                                                   |                   |                                                          |
| Contents                                                                                                                                                                              |                                                                                   |                   |                                                          |
| Semiconductor nanotechnology, self-organisation, optoelectronic components, modern analysis methods, silicon technology<br>technology, wide gap semiconductor devices                 |                                                                                   |                   |                                                          |
| Objective qualification                                                                                                                                                               |                                                                                   |                   |                                                          |
| After completing the module Special Problems in Semiconductor Nanotechnology, students will have knowledge of advanced topics in nanotechnology and improved presentation techniques. |                                                                                   |                   |                                                          |
| Literature                                                                                                                                                                            |                                                                                   |                   |                                                          |
| Will be provided during the lectures.                                                                                                                                                 |                                                                                   |                   |                                                          |

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|                                        |     |                  |          |
|----------------------------------------|-----|------------------|----------|
| <b>Related courses</b>                 |     |                  |          |
| <b>Rules for the choice of courses</b> |     |                  |          |
|                                        |     |                  |          |
| <b>Compulsory attendance</b>           |     |                  |          |
|                                        |     |                  |          |
| Name of the course                     | SWS | Eventtype        | Language |
|                                        | 2,0 | Advanced seminar | german   |
| <b>Literature</b>                      |     |                  |          |
| individuell                            |     |                  |          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Semiconductor Technology |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2413420                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                          | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the summer term  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                        | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                  | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                       | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                          |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Oral exam 30 min         |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                          |                   |                                                          |
| <ul style="list-style-type: none"><li>- physical and chemical basics</li><li>- manufacturing of single crystals and wafers</li><li>- epitaxial crystal growth processes and crystal defects</li><li>- doping processes</li><li>- semiconductor measurement technology</li><li>- planar technology</li><li>- basics of photolithography, deposition processes for dielectrics and etching processes</li></ul>                                                                                                                                                                               |                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                          |                   |                                                          |
| After completing the semiconductor technology module, students have: <ul style="list-style-type: none"><li>• an understanding of the basic manufacturing technologies of semiconductors as well as components and integrated circuits made from them.</li><li>• the ability to recognize the principles of the most modern manufacturing processes in semiconductor technology and their modes of operation</li><li>• the ability to analyze and extrapolate trends in semiconductor technology developments</li></ul>                                                                     |                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                          |                   |                                                          |
| <ul style="list-style-type: none"><li>• Lecture transparencies</li><li>• Script in Englisch (H.-H. Wehmann and A. Schlachetzki)</li><li>• Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(Stuttgart, 1998) ISBN: 3-519-06167-8</li><li>• Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (Berlin, 1991) ISBN: 3-540-53873-9</li><li>• Werner Prost: Technologie der III/V-Halbleiter, Springer (Berlin, 1997) ISBN. 3-540-62804-5</li><li>• Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (Stuttgart, 2004) ISBN: 3-519-30149-0</li></ul> |                          |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                          |                   |                                                          |
| Language German or English                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                          |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Semiconductor Technology                                                                                                                                                                                                                                                                                                                          | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner (1998)<br>Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (1991)<br>Werner Prost: Technologie der III/V-Halbleiter, Springer (1997)<br>Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (2004)<br>Ausführliches Skript in Englisch Vorlesungsfolien |            |                  |                 |
| Semiconductor Technology                                                                                                                                                                                                                                                                                                                          | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| Übungsmaterial wird verteilt.                                                                                                                                                                                                                                                                                                                     |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                           |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Nano- and Bioelectronic System                                                            |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2413560                                                                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                           | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | only in the winter term                                                                   | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                                                                         | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 3 / 5,0                                                                                   | Module owner      | Prof. Dr. Tobias Voß                                     |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 150                                                                                       |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 42                                                                                        | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                           |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Oral exam (30 minutes) or written exam (120 minutes), depending on number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                           |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                           |                   |                                                          |
| Introduction to nanotechnology<br>growth, nanostructuring and characterization processes and tools (lithography, microscopy, raster probe technique, spectroscopy, nanotubes, nanowires, nanoparticles, hybrid nanostructures<br>bio-organic functionalization of surfaces (Langmuir-Blodgett, self-assembled monolayers on metals and semiconductors)<br>semiconductor nano- and biosensors based on different inorganic and organic nanomaterials<br>hybrid nanostructures for optoelectronics  |                                                                                           |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                           |                   |                                                          |
| After completion of the module Nano- and Bioelectronic Systems, the students possess<br>- a basic understanding of the most important techniques for the preparation and characterization of inorganic and hybrid nanoelectronic systems (nanoparticles, nanotubes, nanowires, quantum well structures)<br>- the ability to combine acquired fundamental knowledge to understand and evaluate advanced semiconductor-based nano and biosensors as well as nanoscale hybrid optoelectronic devices |                                                                                           |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                           |                   |                                                          |
| "Nanoelectronics and Information Technology. Advanced Electronic Materials and Novel Devices", R. Waser (Ed.), Wiley-VCH, 2nd Ed. (2005): ISBN-13: 978-3527405428<br>"Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer, 2nd. Ed. (2006): ISBN-13: 978-3540298557                                                                                                                                                                                                                  |                                                                                           |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                           |                   |                                                          |
| primarily master module                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                           |                   |                                                          |



|                                                                                                                                                                                                          |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                          | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                        |            |                  |                 |
| "Nanoelectronics and Information Technology. Advanced Electronic Materials and Novel Devices", R. Waser (Ed.), Wiley-VCH (2003) "Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer (2004) |            |                  |                 |
|                                                                                                                                                                                                          | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                        |            |                  |                 |
| "Nanoelectronics and Information Technology. Advanced Electronic Materials and Novel Devices", R. Waser (Ed.), Wiley-VCH (2003) "Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer (2004) |            |                  |                 |

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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Advanced Quantum Technologies for Engineers          |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2413570                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the winter term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                                    | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                                              | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                                                   | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                      |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Written exam (120 minutes) or oral exam (30 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                      |                   |                                                          |
| <p>Concepts of quantum physics have been developed at the beginning of 20th century, and developed into a comprehensive foundation of physics. Quantum technologies are already used in applications today, like e.g. semiconductor devices, laser devices or satellite navigation. The quantum principles of the first generation of applications are based on the concepts of coherence. Potential technologies of the second generation of quantum technologies will extend towards the manipulation of single quantum objects and will use many particle systems and entanglement. In a joint statement on the importance and commercialization of quantum technologies, the German Academies of Sciences urgently suggest to merge quantum technologies and engineering education. This is the goal of the lecture #Advanced quantum technologies for engineers#. It lays out the basis for an understanding of quantum effects, dealing with the following topics: quantum physics as scientific theory, principles of quantum theory, quantum technologies of 1. and 2. generation. Further information can be found in #Perspectives of quantum technologies# [gemeinsame Stellungnahme von Leopoldina, acatech und Union der deutschen Akademien der Wissenschaften, ISBN 978-3-80473343-5, online available]</p> |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                      |                   |                                                          |
| Knowledge in the basic concepts of quantum physics, basic knowledge in quantum optics, quantum electronics, optoelectronics and laser physics, quantum statistics, spinelectronics as a basis for future applications of quantum technologies.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                      |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                                          |

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|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | english         |
|                                        | 1,0        | Exercise         | english         |

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| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Molecular Electronics   |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2413600                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the summer term | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                       | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                 | Module owner      | Prof. Dr. Tobias Voß                                     |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                      | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Oral exam (30 min)      |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Presentation            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                         |                   |                                                          |
| Introduction to molecular electronics<br>basic considerations (molecular orbitals, conjugated systems)<br>characterisation tools<br>transport mechanisms<br>conductive polymers<br>optoelectronic applications of molecular systems                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |                   |                                                          |
| Students are familiar with the fundamentals of organic chemistry. They can explain the structure of molecular orbitals and describe the different hybridization states of carbon atoms in the context of LCAO. They analyze the electron transfer between different molecules in the framework of the Marcus theory and can describe the essential aspects of electronic tunneling processes. They understand the content of current research publications and present them in short presentations. They can describe the structure of conductive polymers, their doping and electronic transport. They analyze the optoelectronic properties of polymers and organic dyes and can classify and explain the relevant electronic excitations and processes. |                         |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                         |                   |                                                          |
| Introduction to Nanoscience, S.M. Lindsay, Oxford<br>Polymer Electronics, M. Geoghegan, G. Hadzioannou, Oxford                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                         |                   |                                                          |

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| <b>Related courses</b>                                                                                                                                                      |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                             |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                             |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                   | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Molecular Electronics                                                                                                                                                       | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                           |            |                  |                 |
| "Molecular Nanoelectronics", M. A. Reed, T. Lee (Eds.), American Scientific Publishers (2003) "Introducing Molecular Electronics", Cuniberti et al. (Eds.), Springer (2005) |            |                  |                 |
|                                                                                                                                                                             | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                           |            |                  |                 |
| lecture slides, exercise materials                                                                                                                                          |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                     | Optical Communications with Lab                      |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                    | 2415220                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                 |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                        | only in the winter term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                           | 1                                                    | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                     | 4 / 6,0                                              | Module owner      | Prof. Dr. Thomas Schneider                               |
| Workload (h)                                                                                                                                                                                                                                                                                                              | 180                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                      | 56                                                   | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                   |                                                      |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                              | Written exam (120 minutes) or oral exam (30 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                        |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                  |                                                      |                   |                                                          |
| <ul style="list-style-type: none"><li>- Optical fibers</li><li>- Dispersion, velocities of light</li><li>- Coherent modulation</li><li>- Coherent receiver</li><li>- Laser</li><li>- Optical amplifier</li><li>- Optoelectronic modulators</li><li>- Photodetectors</li><li>- Systems of optical communications</li></ul> |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                   |                                                      |                   |                                                          |
| After completing the module, the students understand the mode of operation and know the performance characteristics of different components of optical transmission links. They can design and dimension fibre-optic transmission links.                                                                                  |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                |                                                      |                   |                                                          |
| S. L. Chuang, Physics of Photonic Devices, Wiley & Sons, ISBN 9780470293195                                                                                                                                                                                                                                               |                                                      |                   |                                                          |

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|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

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|------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------|---------|
|                                                                                                                                                            | 2,0 | Lecture    | german  |
| <b>Literature</b>                                                                                                                                          |     |            |         |
| <ul style="list-style-type: none"> <li>- Skript zur Vorlesung</li> <li>- S. L. Chuang, Physics of Optoelectronic Devices, John Wiley &amp; Sons</li> </ul> |     |            |         |
|                                                                                                                                                            | 1,0 | Exercise   | german  |
|                                                                                                                                                            | 1,0 | Laboratory | english |
| <b>Literature</b>                                                                                                                                          |     |            |         |
| Skript zum Praktikum                                                                                                                                       |     |            |         |

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| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Dielectric Materials for Electronics and Photonics           |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2415250                                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                            | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                                      | Module owner      | Prof. Dr. Wolfgang Kowalsky                              |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 42                                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Written exam (120 min) or oral exam (30 min) or presentation |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>- Crystalline solids</li><li>- Reciprocal lattice</li><li>- X-ray deflection</li><li>- Phonons</li><li>- Dielectric properties of insulators (local electric field, mechanisms of polarization, Kramers-Kronig relations)</li><li>- Thermal properties of insulators (Specific heat, thermal expansion, thermal conductivity)</li><li>- Magnetic properties of diamagnetism and paramagnetism</li><li>- Ferro-, antiferro-, and ferrimagnetism</li></ul> |                                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                              |                   |                                                          |
| After completion of the module students have deeper understanding of solid state physics of dielectrics, semiconductors, and metals. They developed the capability to design electronic and optoelectronic devices.                                                                                                                                                                                                                                                                            |                                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>- Skript zur Vorlesung - N. W. Ashcroft, N. D. Mermin, Solid State Physics, Thompson Press, ISBN 8131500527</li><li>- C. Kittel, Einführung in die Festkörperphysik, Oldenbourg, ISBN 3486577239</li></ul>                                                                                                                                                                                                                                               |                                                              |                   |                                                          |

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| <b>Related courses</b>                                                                                                                                  |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                  |            |                  |                 |
|                                                                                                                                                         |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                            |            |                  |                 |
|                                                                                                                                                         |            |                  |                 |
| <b>Name of the course</b>                                                                                                                               | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                         | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                       |            |                  |                 |
| - Skript zur Vorlesung - N. W. Ashcroft, N. D. Mermin, Solid State Physics, Harcourt School - C. Kittel, Einführung in die Festkörperphysik, Oldenbourg |            |                  |                 |
|                                                                                                                                                         | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Optoelectronics                                             |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2415290                                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the summer term                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                                           | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                                                     | Module owner      | Prof. Dr. Wolfgang Kowalsky                              |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Written exam (90 min) or oral exam (30 min) or presentation |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                             |                   |                                                          |
| <div>- Propagation of electromagnetic waves in free space and in guiding structures</div> <div>- Refraction, reflexion, total reflexion at dielectric interfaces</div> <div>- Optical guiding in film and strip waveguides, mechanisms of losses</div> <div>- Optical modes and theoretical description</div> <div>- field distribution in step and gradient profiles, analogy to quantum mechanics</div> <div>- Periodic structures to distributed feedback: DFB, DBR</div> <div>- Electrooptical interaction, directional couplers</div> |                                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                             |                   |                                                          |
| After completion of the module students have gained knowledge in the functional mechanisms and the design of devices for integrated optics, particularly of waveguides. They are able to apply these competences in the analysis of optoelectronic systems with regard to device and circuit level and to qualify and optimize these systems.                                                                                                                                                                                              |                                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                             |                   |                                                          |
| K. J. Ebeling, Integrierte Optoelektronik, Springer, ISBN 3540546553                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                             |                   |                                                          |



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|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |



|  |     |          |        |
|--|-----|----------|--------|
|  | 2,0 | Lecture  | german |
|  | 1,0 | Exercise | german |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Organic Optoelectronics                     |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2415430                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                           | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 3 / 5,0                                     | Module owner      | Prof. Dr. Wolfgang Kowalsky                              |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                 | written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
| <div>- Applications of organic materials in electronics and optics</div> <div>- Molecular structure and chem. bonds</div> <div>- Charge injection, charge transport in organic semiconductors</div> <div>- Electrooptical Processes</div> <div>- Process technology for organic materials</div> <div>- Applications: Organic light emitting diodes, lasers, solar cells, transistors, sensors</div>                                                                                          |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| <div>After completion of the module, students will know the physical fundamentals of charge transport and optical processes in organic semiconductors, the structure of optoelectronic components made of these substances and the associated process technology.</div> <div>The students are able to apply this knowledge in the analysis of optoelectronic organic devices and their special properties and to evaluate and optimize the relevant system and device characteristics.</div> |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| Schwoerer, Wolf, Organische Molekulare Festkörper, Wiley-VCH, ISBN 3527405399                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |



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|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|  |     |          |        |
|--|-----|----------|--------|
|  | 1,0 | Exercise | german |
|  | 2,0 | Lecture  | german |

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| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Organic Optoelectronics                                       |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2415440                                                       | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                               | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term                                       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                                             | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 6 / 8,0                                                       | Module owner      | Prof. Dr. Wolfgang Kowalsky                              |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 240                                                           |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 84                                                            | Self studying (h) | 156                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                               |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                    | written examination 90 minutes or oral examination 30 minutes |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                               |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                               |                   |                                                          |
| <div>- Applications of organic materials in electronics and optics</div> <div>- Molecular structure and chem. bonds</div> <div>- Charge injection, charge transport in organic semiconductors</div> <div>- Electrooptical Processes</div> <div>- Process technology for organic materials</div> <div>- Applications: Organic light emitting diodes, lasers, solar cells, transistors, sensors</div>                                                                                          |                                                               |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                               |                   |                                                          |
| <div>After completion of the module, students will know the physical fundamentals of charge transport and optical processes in organic semiconductors, the structure of optoelectronic components made of these substances and the associated process technology.</div> <div>The students are able to apply this knowledge in the analysis of optoelectronic organic devices and their special properties and to evaluate and optimize the relevant system and device characteristics.</div> |                                                               |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                               |                   |                                                          |
| Schwoerer, Wolf, Organische Molekulare Festkörper, Wiley-VCH, ISBN 3527405399                                                                                                                                                                                                                                                                                                                                                                                                                |                                                               |                   |                                                          |

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|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|  |     |            |        |
|--|-----|------------|--------|
|  | 1,0 | Exercise   | german |
|  | 3,0 | Laboratory | german |
|  | 2,0 | Lecture    | german |

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| Title                                                                                                                                                                                                                                                                                                                                                          | Nonlinear Photonics                                |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                         | 2415470                                            | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                      |                                                    | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                             | only in the winter term                            | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                | 1                                                  | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                          | 4 / 5,0                                            | Module owner      | Prof. Dr. Thomas Schneider                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                   | 150                                                |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                           | 56                                                 | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                        |                                                    |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                      | Written exam, 90 minutes, or oral exam, 30 minutes |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                             |                                                    |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                       |                                                    |                   |                                                          |
| <div>- Basics of linear optics</div> <div>- 2nd order nonlinear optical effects</div> <div>- 3rd order nonlinear optical effects</div> <div>- Nonlinear scattering</div> <div>- Optical telecommunications</div> <div>- Nonlinear effects in optical fibers</div> <div>- Suppression of nonlinear effects</div> <div>- Applications of nonlinear effects</div> |                                                    |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                        |                                                    |                   |                                                          |
| After a successful participation, the students know the main basics of nonlinear photonics and will be able to use them for the evaluation of optical systems and optical data transmission systems.                                                                                                                                                           |                                                    |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                     |                                                    |                   |                                                          |
| T. Schneider "#Nonlinear Optics in Telecommunications#", Springer Verlag                                                                                                                                                                                                                                                                                       |                                                    |                   |                                                          |

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|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

|                     |     |          |         |
|---------------------|-----|----------|---------|
| Nonlinear Photonics | 2,0 | Lecture  | english |
| Nonlinear Photonics | 2,0 | Exercise | english |

| Title                                                                                                                                                                                                                                                                                            | Linear photonics with practical course      |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                           | 2415500                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                        |                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                               | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                  | 1                                           | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                            | 6 / 8,0                                     | Module owner      | Prof. Dr. Thomas Schneider                               |
| Workload (h)                                                                                                                                                                                                                                                                                     | 240                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                             | 84                                          | Self studying (h) | 156                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                        | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                               | Lab work                                    |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| Ray optics, wave optics, Fourier optics, electromagnetic optics, quantum optics with practical experiments on: lenses, imaging, refraction, diffraction, interferometers, determination of optical constants, polarisation, Fourier optics, holography, laser, waveguide optics, quantum optics. |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| After completing the module, the students know the essential fundamentals of modern photonics and can apply this knowledge to the assessment, design and simulation of photonic systems. Through the practical experiments offered, the students gain additional practical experience.           |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| B.E.A. Saleh, M.C. Teich, Fundamentals of Photonics, (Wiley Series in Pure and Applied Optics)                                                                                                                                                                                                   |                                             |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |
|                                        | 2,0 | Lecture   | german   |
|                                        | 2,0 | Exercise  | german   |



|                                                                                                |     |            |        |
|------------------------------------------------------------------------------------------------|-----|------------|--------|
|                                                                                                | 2,0 | Internship | german |
| <b>Literature</b>                                                                              |     |            |        |
| B.E.A. Saleh, M.C. Teich, Fundamentals of Photonics, (Wiley Series in Pure and Applied Optics) |     |            |        |

| Title                                                                                                                                                                                                                                                                                            | Linear Photonics                            |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                           | 2415510                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                        |                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                               | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                  | 1                                           | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                            | 4 / 5,0                                     | Module owner      | Prof. Dr. Thomas Schneider                               |
| Workload (h)                                                                                                                                                                                                                                                                                     | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                             | 56                                          | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                        | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                               |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| Ray optics, wave optics, Fourier optics, electromagnetic optics, quantum optics with practical experiments on: lenses, imaging, refraction, diffraction, interferometers, determination of optical constants, polarisation, Fourier optics, holography, laser, waveguide optics, quantum optics. |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| After completing the module, the students know the essential basics of modern photonics and are thus able to assess photonic and optical systems and technologies.                                                                                                                               |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| B. E. A. Saleh, M. C. Teich #Fundamentals of Photonics# John Wiley & Sons                                                                                                                                                                                                                        |                                             |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |
|                                        | 2,0 | Lecture   | german   |
|                                        | 2,0 | Exercise  | german   |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                       | Numerical Calculation of Radiation Properties |                   |                                                               |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2419070                                       | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                               | Language          | german                                                        |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the summer term                       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                                             | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                       | 3 / 5,0                                       | Module owner      |                                                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                                           |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                        | 42                                            | Self studying (h) | 108                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                     |                                               |                   |                                                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                   | Written exam (60 min) or oral exam (30 min)   |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                          |                                               |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                               |                   |                                                               |
| <div>- quantitative description of radiation properties by special numerical calculation methods</div> <div>- theoretical concepts of mainstream methods (FE, FD, MoM) and newer approaches (i.a. wavelets)</div> <div>- criteria of bandwidth and complexity of boundary conditions</div> <div>- practical sample applications from EMC (absorption in technical materials and biological tissue, shielding and antenna development)</div> |                                               |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                     |                                               |                   |                                                               |
| The students are able to specify suited numerical solution procedures for electromagnetic radiation problems. The underlying approaches of the procedures are understood, as well as the herefrom resulting limits for the application and potential sources of error.                                                                                                                                                                      |                                               |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                               |                   |                                                               |
| #Arnulf Kost, Numerische Methoden in der Berechnung elektromagnetischer Felder, Springer-Verlag, Berlin, 1994, ISBN 3-540-55005-4 #<br>Matthew N.O. Sadiku, Numerical Techniques in Electromagnetics, CRC Press, Boca Raton, 2001, ISBN 0-8493-1395-3                                                                                                                                                                                       |                                               |                   |                                                               |

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|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|  |     |          |        |
|--|-----|----------|--------|
|  | 2,0 | Lecture  | german |
|  | 1,0 | Exercise | german |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|---------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Electromagnetic Compatibility               |                   |                                                               |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2419120                                     | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                             | Language          | german                                                        |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                           | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3 / 5,0                                     | Module owner      | Prof. Dr. Thomas Kleine-Ostmann<br>Dr. Harald Spieker         |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                         |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 42                                          | Self studying (h) | 108                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written exam (60 min) or oral exam (30 min) |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                               |
| <ul style="list-style-type: none"><li>• Terms and definitions of EMC</li><li>• Sources of interference and disturbance variables, immunity of susceptible devices #</li><li>• Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference #</li><li>• Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection #</li><li>• Legal basis, product liability, standardization #</li><li>• EMC test engineering #</li><li>• Electromagnetic compatibility of biological systems</li></ul> |                                             |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                               |
| The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able assess the EMC product safety by failure mechanisms.    |                                             |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                               |
| <ul style="list-style-type: none"><li>- Lecture notes</li><li>- Joachim Franz, EMV – Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X</li><li>- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1</li><li>- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9</li></ul>                                                                                                                                                                                                                                 |                                             |                   |                                                               |



| <b>Related courses</b>                                                              |            |                  |                 |
|-------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>                                              |            |                  |                 |
| Either this module or "Electromagnetic Compatibility with Seminar" can be selected. |            |                  |                 |
| <b>Compulsory attendance</b>                                                        |            |                  |                 |
|                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Electromagnetic Compatibility                                                       | 2,0        | Lecture          | german          |
| Electromagnetic Compatibility                                                       | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Electromagnetic Compatibility with Seminar                        |                   |                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2419130                                                           | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                   | Language          | english german                                                |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | only in the winter term                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1                                                                 | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 5 / 6,0                                                           | Module owner      | Prof. Dr. Thomas Kleine-Ostmann                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 180                                                               |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 70                                                                | Self studying (h) | 110                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                   |                                                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Written exam (60 min) or oral exam, presentation of seminar topic |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                   |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                   |                   |                                                               |
| <ul style="list-style-type: none"><li>- Terms and definitions of EMC</li><li>- Sources of interference and disturbance variables, immunity of susceptible devices</li><li>- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference</li><li>- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection</li><li>- Legal basis, product liability, standardization</li><li>- EMC test engineering</li><li>- Electromagnetic compatibility of biological systems</li><li>- Current EMC issues presented in seminar talks</li></ul>                                                                    |                                                                   |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                   |                                                               |
| The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able to assess the EMC product safety by failure mechanisms. The students are able to investigate current EMC issues autonomously, structure and present them to an audience. |                                                                   |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                   |                   |                                                               |
| <ul style="list-style-type: none"><li>- continuously updated script handout</li><li>- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X</li><li>- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1</li><li>- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9</li></ul>                                                                                                                                                                                                                                                                                                                            |                                                                   |                   |                                                               |



|                                                                                                                                                                                                                            |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                     |            |                  |                 |
| You can either choose Electromagnetic Compatibility with Seminar <b>or</b> Electromagnetic Compatibility (without seminar). The seminar can also be attended in the summer semester after having attended the EMC lecture. |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Electromagnetic Compatibility                                                                                                                                                                                              | 2,0        | Lecture          | german          |
| Teacher training college EMC                                                                                                                                                                                               | 2,0        | Seminar          | english         |
| Electromagnetic Compatibility                                                                                                                                                                                              | 1,0        | Exercise         | german          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                     |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Analog Integrated Circuits with Lab |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2420140                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                     | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the summer term             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                   | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 6 / 8,0                             | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 240                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 84                                  | Self studying (h) | 156                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                     |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Oral exam (30 min)                  |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                     |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                     |                   |                                                          |
| <p>All modern mobile communications applications (e.g., GSM, WLAN, GPS, Bluetooth, DECT, etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are increasingly being integrated into low-cost CMOS technology, resulting in significant differences from the classic design of high-frequency circuits based on discrete components. The lecture provides an introduction to the design of analog, integrated CMOS mobile communications receiver circuits.</p> <p>The lecture is divided into the following chapters:</p> <ul style="list-style-type: none"><li>• High-frequency amplifier circuits</li><li>• Simulation of electronic noise</li><li>• Low-noise input amplifiers in CMOS</li><li>• Mixer circuits</li><li>• HPhase-locked loops (PLLs)</li><li>• Voltage-controlled oscillators</li></ul>                                                                                                                                                                                                                        |                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                     |                   |                                                          |
| <p>After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).</p> <p>They will acquire fundamental knowledge in the use of the Spectre-RF design tool, which is widely used in industry for the design of analog integrated circuits.</p> <p>In accordance with the didactic concept of the course and the structure of the individual components, interdisciplinary skills are taught and practiced. These include scientific writing and documentation, conversation</p> |                                     |                   |                                                          |

and presentation techniques, and teamwork in the laboratory or on projects, which are covered in assignments, colloquia, and final presentations.

**Literature**

# Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press

**Remark**

For the Master's degree programs in Electrical Engineering, Industrial Engineering Electrical Engineering, and Information Systems Engineering



**Related courses**

**Rules for the choice of courses**

Requirements for this module: circuit technology (*Schaltungstechnik*, ST)

**Compulsory attendance**

| Name of the course                | SWS | Eventtype  | Language |
|-----------------------------------|-----|------------|----------|
| Analog Integrated Circuits (2013) | 1,0 | Exercise   | english  |
| Analog Integrated Circuits (2013) | 1,0 | Internship | english  |
| Analog Integrated Circuits (2013) | 2,0 | Lecture    | english  |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Analog Integrated Circuits |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2420150                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                          | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                    | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                         | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam 30 min           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                   |                                                          |
| <p>All modern mobile radio applications (e.g. GSM, WLAN, GPS, Bluetooth, Dect. etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are increasingly being integrated in low-cost CMOS technology, which results in significant differences to the classic design of high-frequency circuits based on discrete components. The lecture gives an introduction to the design of analog, integrated CMOS mobile radio receiver circuits.</p> <p>The lecture is divided into the following chapters:</p> <ul style="list-style-type: none"><li>- High frequency amplifier circuits</li><li>- Simulation of electronic noise</li><li>- Low-noise input amplifiers in CMOS</li><li>- Mixer circuits</li><li>- Phase-locked loops (PLLs)</li><li>- Voltage-controlled oscillators</li></ul> |                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| <p>After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                   |                                                          |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits" Cambridge University Press                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |

↑

| <b>Related courses</b>                            |            |                  |                 |
|---------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>            |            |                  |                 |
| Prerequisite for this module: Circuit Design (ST) |            |                  |                 |
| <b>Compulsory attendance</b>                      |            |                  |                 |
|                                                   |            |                  |                 |
| <b>Name of the course</b>                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Analog Integrated Circuits (2013)                 | 1,0        | Exercise         | english         |
| Analog Integrated Circuits (2013)                 | 2,0        | Lecture          | english         |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Integrated Circuits for Biomedical Applications |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2420190                                         | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                 | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the winter term                         | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                               | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                         | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                             |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                                              | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                 |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam (30 min) or written exam (90 min)     |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                 |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                 |                   |                                                          |
| <ul style="list-style-type: none"><li>- Introduction to biomedical applications</li><li>- Biosensing principles (physical, electrical and electrochemical)</li><li>- Basic biomedical circuits: transimpedance and instrumentation amplifiers, oscillators, ADCs/DACs</li><li>- Basic circuits for Power Management (DCDC, LDO, Rectifier)</li><li>- Self-powering and energy storage (e.g. biofuel cell sensing, energy harvesting)</li><li>- Wireless Power Transfer (WPT) for implantable devices</li><li>- Circuits for ultra-low power data transmission</li><li>- Circuits for electrochemical sensing (potentiometric and amperometric)</li><li>- Examples of potentiometric biosensors (pH, K+, Na+, Ca+ etc) and iontophoresis</li><li>- Circuits for Impedance Spectroscopy</li><li>- Radar-based Imaging for Breast Cancer Detection</li><li>- Circuits for Electrical Impedance Tomography</li><li>- Resonance-based dielectric sensors (e.g. for glucose detection)</li><li>- Circuits for cochlear implants</li></ul> |                                                 |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                 |                   |                                                          |
| Upon completion of this module, the students will acquire knowledge about integrated circuits for various biomedical applications and obtain a deep understanding about circuit techniques for design of analog integrated circuits for biomedical applications (e.g. HF-oscillators for glucose sensing).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |
| “Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems”, Rahul Sarpeshkar, Cambridge University Press, 2010<br>“Power Management Integrated Circuits (Devices, Circuits, and Systems)”, M. Hella, P. Mercier, CRC Press, 2016<br>“Introduction to Biosensors From Electric Circuits to Immunosensors”, J.-Y. Yoon, Springer 2016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                            | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
| Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems, Rahul Sarpeshkar, Cambridge University Press, 2010<br>Power Management Integrated Circuits (Devices, Circuits, and Systems), M. Hella, P. Mercier, CRC Press, 2016<br>Introduction to Biosensors From Electric Circuits to Immunosensors, J.-Y. Yoon, Springer 2016 |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Exercise         | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
| Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems, Rahul Sarpeshkar, Cambridge University Press, 2010<br>Power Management Integrated Circuits (Devices, Circuits, and Systems), M. Hella, P. Mercier, CRC Press, 2016<br>Introduction to Biosensors From Electric Circuits to Immunosensors, J.-Y. Yoon, Springer 2016 |            |                  |                 |

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|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Low power CMOS data converter circuit design |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2420210                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | irregular                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                            | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                      | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 36                                           | Self studying (h) | 114                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Oral exam (30 min)                           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| <p>Data converters bridge digital virtual space and analog real world in cyber physical system (CPS), and become key building circuit blocks. This lecture deals with the circuit design of CMOS data converters. In particular, circuit techniques related to low-power and high-resolution ADCs, which are important for sensor signal detection in IoT application, will be explained. It is assumed that the students have basic knowledge of CMOS integrated circuit design and signal processing such as Laplace transform and Z transform.</p> <p>General introduction of data converters</p> <p>1. Data converter application areas</p> <p>Sensor interface, Communication (wireless/wireline)</p> <p>2. Basic theory in data conversion</p> <p>Sampling/Quantization, Performance metric (INL/DNL, SNDR, SFDR, ENOB, FoM)</p> <p>3. Architectures and features of data converters</p> <p>2-1. High resolution data converter (SAR, ##, VCO based)</p> <p>2-2. High speed data converter (Flash, Pipeline)</p> <p>Implementation of low-power and high-resolution CMOS integrated ADCs</p> <p>4. Building blocks of ADC</p> <p>Comparator, operational amplifier</p> <p>5. SAR-ADC with charge redistribution.</p> <p>3-1. Power reduction techniques</p> <p>3-2. Resolution enhancement techniques (digital calibration etc.)</p> <p>6. High resolution ## modulator</p> <p>7. Time based (VCO based) ADC</p> <p>8. Hybrid-ADC</p> <p>9. Characterization of data converters</p> |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                              |                   |                                                          |

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| Related courses                 |     |              |          |
|---------------------------------|-----|--------------|----------|
| Rules for the choice of courses |     |              |          |
|                                 |     |              |          |
| Compulsory attendance           |     |              |          |
|                                 |     |              |          |
| Name of the course              | SWS | Eventtype    | Language |
|                                 | 3,0 | Block course | english  |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                            |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Applied Quantum Computing: Basics and Devices                                              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2413620                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                            | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the winter term                                                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                                                                          | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3 / 5,0                                                                                    | Module owner      | Prof. Dr. Stefanie Kroker                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                                                                                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                                                                                         | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                            |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (120 min) or oral exam (30 min), alternativ: homework with final presentation |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                            |                   |                                                          |
| <ul style="list-style-type: none"><li>- Basics of Quantum Mechanics</li><li>- From Bit to Qubit</li><li>- Quantum Circuits I</li><li>- Quantum Circuits II</li><li>- Entanglement and Teleportation</li><li>- Algorithms of Quantum Computing</li><li>- Quantum Hardware I</li><li>- Quantum Hardware II</li></ul>                                                                                                                                                                                                                                                                                                                                                              |                                                                                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                            |                   |                                                          |
| <ul style="list-style-type: none"><li>- The students can name the prerequisites for the realization of qubits as well as typical platforms and explain their significance.</li><li>- Students will be able to name the strengths and weaknesses of different hardware platforms in common application scenarios and weigh them against each other.</li><li>- The students can name the essential process steps for the realization of different quantum computer platforms and to explain challenges that may arise in the manufacturing process.</li><li>- Students will be able to use an exemplary platform to explain how selected quantum gates can be realized.</li></ul> |                                                                                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                            |                   |                                                          |
| <p>[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019</p> <p>[2] M. A. Nielsen &amp; I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010</p> <p>[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019</p> <p>[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018</p> <p>[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019</p>                                                                                                                                                                                                                                      |                                                                                            |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Applied Quantum Computing: Basics and Devices                                                                                                                                                                                                                                                                                                                                                                   | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| [1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019<br>[2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010<br>[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019<br>[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018<br>[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019 |            |                  |                 |
| Applied Quantum Computing: Basics and Devices                                                                                                                                                                                                                                                                                                                                                                   | 1,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Lighting Engineering                        |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2413320                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                           | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 3 / 5,0                                     | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | oral exam (30 min) or written exam (90 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| <p>The module provides an overview of lighting technology, from the physical principles of light and lighting to the manufacture of light sources, luminaires and the relevant DIN standards. Special focus: Lighting technology and lighting technology for the automotive sector</p> <ul style="list-style-type: none"><li>• Introduction and overview</li><li>• The nature of light: physical principles</li><li>• The human perception of light</li><li>• Production and design of light sources</li><li>• Module structure</li><li>• Energy balances</li><li>• Standardisation</li><li>• Applications (lighting technology, Automotive Lighting)</li></ul> <p>[Lighting technology (V)]</p> <p>The module provides an overview of lighting technology, from the physical principles of light and lighting to the manufacture of light sources and luminaires. After completing the module, students will be able to characterise light sources and illuminants, optimise their efficiency and solve simple lighting technology problems with the help of their parameters.</p> <p>[Lighting technology (Ü)]</p> <ul style="list-style-type: none"><li>• Introduction and overview</li><li>• The nature of light: physical principles</li><li>• The human perception of light</li><li>• Production and construction of light sources</li><li>• Module structure</li><li>• Energy balances</li><li>• Standardisation</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |

After completing the module, students will be able to characterise light sources and illuminants, optimise their efficiency and solve simple lighting technology problems with the help of their parameters.

#### Literature

Lecture notes and slides

Hans-Jürgen Hentschel (Hrsg.): Licht und Beleuchtung; Hüthig 2002, ISBN 3-7785-2817-3

Horst Lange (Hrsg.): Handbuch für Beleuchtung; Landsberg 2007, ISBN 978-3-609-75390-4



#### Related courses

#### Rules for the choice of courses

#### Compulsory attendance

| Name of the course                                                                                                  | SWS | Eventtype | Language |
|---------------------------------------------------------------------------------------------------------------------|-----|-----------|----------|
|                                                                                                                     | 2,0 | Lecture   | german   |
| <b>Literature</b>                                                                                                   |     |           |          |
| Vorlesungsfolien und Kurzschrift Hans-Jürgen Hentschel: Licht und Beleuchtung Horst Lange: Handbuch für Beleuchtung |     |           |          |
|                                                                                                                     | 1,0 | Exercise  | german   |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Gallium Nitride Technology                  |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2413000030                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                     | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| <p>The course builds on 'Lighting Technology I'. While Lighting Technology I focusses on general questions of lighting and lighting technology, this course discusses LED technology and gallium nitride technology in particular:</p> <ul style="list-style-type: none"><li>• Physical principles of LEDs. Band gap engineering in LEDs.</li><li>• Semiconductor materials for optoelectronics</li><li>• Relationship between material properties and LED properties</li><li>• Manufacturing processes</li><li>• Efficiency considerations</li><li>• Front-end and back-end processing</li><li>• Application examples in general lighting, automotive technology, sensor technology</li><li>• Infrared LEDs, visible light, UV LEDs</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| After completing the module, students will have an overview of the current state of LED technology and the development opportunities that solid state lighting will offer in the future. In addition, they will have a basic understanding of the physical processes within LEDs.                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |

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|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Gallium Nitride Technology             | 2,0        | Lecture          | german          |
| Gallium Nitride Technology             | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                          | Semiconductor Optics                                                                                                            |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                         | 1511000010                                                                                                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                 | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                             | irregular                                                                                                                       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                                                                                               | Institution       | Institut für Physik der Kondensierten Materie            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                                                                                                         | Module owner      | Prof. Dr. Farsane Tabataba-Vakili                        |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                                                                                                             |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                           | 42                                                                                                                              | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                 |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                       | Fundamentals of solid state physics, quantum mechanics, optics/electrodynamics from Bachelor's degree in physics or equivalent. |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                   | oral exam (20 min) or written exam (90 min)                                                                                     |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                 |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                 |                   |                                                          |
| Phonons, semiconductor band structure, bulk semiconductors, heterostructures and quantum wells, macroscopic optical properties, interband absorption, excitons, luminescence, cavity exciton-polaritons, 2D materials, excitons in 2D semiconductors, heterostructures of 2D semiconductors                                                                                                                    |                                                                                                                                 |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                 |                   |                                                          |
| The students are able to explain the physical fundamentals of crystalline solids relevant to semiconductor optics. They acquire a detailed understanding of the interaction between light and matter, with a focus on the optical properties of semiconductors. The students gain an overview of exciton physics, particularly in 2D semiconductors, including discussions of current research topics.         |                                                                                                                                 |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                 |                   |                                                          |
| <ul style="list-style-type: none"><li>• Fox: Optical Properties of Solids,</li><li>• Davies: The Physics of low-dimensional semiconductors,</li><li>• Yu and Cardona: Fundamentals of Semiconductors,</li><li>• Kalt and Klingshirn: Semiconductor Optics 1,</li><li>• Grundmann: The Physics of Semiconductors,</li><li>• Marx und Gross: Festkörperphysik,</li><li>• Hungklinger: Festkörperphysik</li></ul> |                                                                                                                                 |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Semiconductor Optics                                                                                                                                                                                                                                                                                                                                                                                                   | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Fox: Optical Properties of Solids,</li> <li>• Davies: The Physics of low-dimensional semiconductors,</li> <li>• Yu and Cardona: Fundamentals of Semiconductors,</li> <li>• Kalt and Klingshirn: Semiconductor Optics 1,</li> <li>• Grundmann: The Physics of Semiconductors,</li> <li>• Marx und Gross: Festkörperphysik,</li> <li>• Hungklinger: Festkörperphysik</li> </ul> |            |                  |                 |
| Semiconductor Optics                                                                                                                                                                                                                                                                                                                                                                                                   | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Fox: Optical Properties of Solids,</li> <li>• Davies: The Physics of low-dimensional semiconductors,</li> <li>• Yu and Cardona: Fundamentals of Semiconductors,</li> <li>• Kalt and Klingshirn: Semiconductor Optics 1,</li> <li>• Grundmann: The Physics of Semiconductors,</li> <li>• Marx und Gross: Festkörperphysik,</li> <li>• Hungklinger: Festkörperphysik</li> </ul> |            |                  |                 |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Phase-Locked Loops and Frequency Synthesis  |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2420000020                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1                                           | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3 / 5,0                                     | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Basic knowledge in analogue circuits        |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | oral exam (30 min) or written exam (60 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                          |
| <div>- System overview</div> <div>- Jitter and phase noise</div> <div>- Basic PLL architectures</div> <div>- Analog integer PLL</div> <div>- Digital integer PLL</div> <div>- Fractional PLL</div> <div>- Clock data recovery</div> <div>- Delay locked loop</div> <div>- Numerically controlled oscillator</div> <div>- Software PLL</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| <p>Upon completion of the module, students will have a comprehensive understanding of the fundamentals and advanced concepts of phase-locked loops (PLLs) and frequency synthesis. They will be familiar with the systematic architecture of various PLL types, including analog and digital integer PLLs as well as fractional PLLs. Students will understand the causes and effects of jitter and phase noise, and will be able to evaluate and minimize them. They will be acquainted with specialized circuits such as Costas loops, delay locked loops (DLL), numerically controlled oscillators (NCOs), and software-based PLL implementations. The knowledge they acquire enables students to independently research related topics and apply theory to practice. This allows them to analyze and solve practical problems independently.</p> |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| <p>Best, Roland E., Phase-Locked Loops: Design, Simulation, and Applications. 6. Auflage, McGraw-Hill Education, 2007</p> <p>Behzad Razavi "Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level", Cambridge University Press, 2020</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |



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|-------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                        |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                        |            |                  |                 |
|                                                                                                                               |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                  |            |                  |                 |
|                                                                                                                               |            |                  |                 |
| <b>Name of the course</b>                                                                                                     | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Phase-Locked Loops and Frequency Synthesis                                                                                    | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                             |            |                  |                 |
| Best, Roland E., Phase-Locked Loops: Design, Simulation, and Applications. 6. Auflage, McGraw-Hill Education, 2007.           |            |                  |                 |
| Behzad Razavi "Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level", Cambridge University Press, 2020 |            |                  |                 |
| Phase-Locked Loops and Frequency Synthesis                                                                                    | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                             |            |                  |                 |
| Best, Roland E., Phase-Locked Loops: Design, Simulation, and Applications. 6. Auflage, McGraw-Hill Education, 2007.           |            |                  |                 |
| Behzad Razavi "Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level", Cambridge University Press, 2020 |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Nanostructures on Surfaces                   |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1520000010                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | irregular                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                            | Institution       | Institut für Angewandte Physik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                                      | Module owner      | Prof. Dr. Uta Schlickum                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Oral exam (30 min) or written exam (120 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              |                   |                                                          |
| 1. Physics at Surfaces, A. Zangwill, Cambridge University Press, 1988<br>2. Oberflächenphysik des Festkörpers, M. Henzler und W. Göpel, Teubner Studienbücher, 1994<br>3. Oberflächenphysik, Grundlagen und Methoden, T. Fauster, L. Hammer, K. Heinz, und M.A. Schneider, Oldenbourg Verlag München, 2013<br>4. Scanning Probe Microscopy and Spectroscopy, R. Wiesendanger, Cambridge University Press, 1994<br>5. Applied Scanning Probe Methods, B. Bhushan, H. Fuchs, und S. Hosaka, Springer Berlin Heidelberg, 2004 |                                              |                   |                                                          |

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|                                 |     |           |          |
|---------------------------------|-----|-----------|----------|
| Related courses                 |     |           |          |
| Rules for the choice of courses |     |           |          |
|                                 |     |           |          |
| Compulsory attendance           |     |           |          |
|                                 |     |           |          |
| Name of the course              | SWS | Eventtype | Language |

|                                                                                                                                                                                                                                                                                                                                                                                                        |     |                  |        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------------|--------|
| Nanostructures on Surfaces                                                                                                                                                                                                                                                                                                                                                                             | 3,0 | Lecture/Exercise | german |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                      |     |                  |        |
| <ol style="list-style-type: none"><li>1. Physics at Surfaces, A. Zangwill, Cambridge University Press, 1988</li><li>2. Oberflächenphysik des Festkörpers, M. Henzler und W. Göpel, Teubner Studienbücher, 1994</li><li>3. Oberflächenphysik, Grundlagen und Methoden, T. Fauster, L. Hammer, K. Heinz, und M.A. Schneider, Oldenbourg Verlag München, 2013</li><li>4. Aktuelle Publikationen</li></ol> |     |                  |        |

| Title                                        | Materials and Device Analysis               |                   |                                                          |
|----------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                       | 2413000050                                  | Module version    |                                                          |
| Shorttext                                    |                                             | Language          | english                                                  |
| Frequency of offer                           | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                              | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                        | 3 / 5,0                                     | Module owner      | Prof. Dr. Tobias Voß                                     |
| Workload (h)                                 | 150                                         |                   |                                                          |
| Class attendance (h)                         | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                      |                                             |                   |                                                          |
| Expected performance/<br>Type of examination | written exam (30 min) or oral exam (60 min) |                   |                                                          |
| Course achievement                           |                                             |                   |                                                          |

#### Contents

With a focus on optical and electrical characterisation methods, procedures for the investigation of materials and devices from the field of semiconductor technology are presented:

1. optical spectroscopy and microscopy methods
  1. absorption spectroscopy
  2. fluorescence spectroscopy
  3. time-resolved spectroscopy
  4. IR spectroscopy
  5. Raman spectroscopy and microscopy
  6. photon correlation spectroscopy
2. scanning electron microscopy
3. x-ray diffraction
4. atomic force microscopy
5. electrical measurement techniques
  1. IV
  2. CV
  3. hall effect measurements
  4. Electrical measurement methods in the atomic force microscope

The methods are each explained on the basis of application fields with typical material systems, whereby silicon, III-V/II-VI semiconductors, group III nitrides and common substrate materials (SiC, sapphire) are discussed.

#### Objective qualification

Students are familiar with important optical, electrical and other characterisation methods used in the field of semiconductor technology. They will be able to select suitable methods for specific materials and components and explain and evaluate the information that can be obtained in each case. They will be able to describe the fundamental processes in the material in the respective measurement methods using technical terminology and will be able to plot, analyse and discuss individual measurement results provided.

#### Literature



#### Related courses

##### Rules for the choice of courses

##### Compulsory attendance

##### Name of the course

##### SWS

##### Eventtype

##### Language

Materials and Device Analysis

2,0

Lecture

english

Materials and Device Analysis

1,0

Exercise

english

| Title                                                                                                                                                                                                                                                                                             | Sensor Technology                                                                                                                                             |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                            | 2413000040                                                                                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                         |                                                                                                                                                               | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                | only in the summer term                                                                                                                                       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                   | 1                                                                                                                                                             | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                             | 3 / 5,0                                                                                                                                                       | Module owner      |                                                          |
| Workload (h)                                                                                                                                                                                                                                                                                      | 150                                                                                                                                                           |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                              | 42                                                                                                                                                            | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                           |                                                                                                                                                               |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                                          | Attending Materials & Device Analysis; Fundamentals of NanoOptics; Integrated Circuits for Biomedical Applications in addition to the lecture is recommended. |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                         | Written exam (60 min) or oral exam (30 min)                                                                                                                   |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                | Project work (design project), either with written assignment or final presentation/colloquium                                                                |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                          |                                                                                                                                                               |                   |                                                          |
|                                                                                                                                                                                                                                                                                                   |                                                                                                                                                               |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                           |                                                                                                                                                               |                   |                                                          |
|                                                                                                                                                                                                                                                                                                   |                                                                                                                                                               |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                        |                                                                                                                                                               |                   |                                                          |
| Core Texts: <ul style="list-style-type: none"><li>• Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010</li><li>• Horowitz &amp; Hill: The Art of Electronics (2nd ed), CUP, 1989</li></ul>                                                                                           |                                                                                                                                                               |                   |                                                          |
| Supplementary: <ul style="list-style-type: none"><li>• Pallás-Areny &amp; Webster: Analog Signal Processing, Wiley, 1999</li><li>• MIT OCW readings &amp; lecture notes from MAS#836 Sensor Technologies</li><li>• Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)</li></ul> |                                                                                                                                                               |                   |                                                          |



|                                                                                                                                                                                                                                                                                        |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                 |            |                  |                 |
|                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                           |            |                  |                 |
|                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Sensor Technology                                                                                                                                                                                                                                                                      | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                      |            |                  |                 |
| Core Texts:                                                                                                                                                                                                                                                                            |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010</li> <li>• Horowitz &amp; Hill: The Art of Electronics (2nd ed), CUP, 1989</li> </ul>                                                                                         |            |                  |                 |
| Supplementary:                                                                                                                                                                                                                                                                         |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Pallás-Areny &amp; Webster: Analog Signal Processing, Wiley, 1999</li> <li>• MIT OCW readings &amp; lecture notes from MAS#836 Sensor Technologies</li> <li>• Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)</li> </ul> |            |                  |                 |
| Sensor Technology                                                                                                                                                                                                                                                                      | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                      |            |                  |                 |
| Project and sensor type-specific; s. lecture for literature and provided articles.                                                                                                                                                                                                     |            |                  |                 |



**Major Specialisation: Metrology and Measurement Technology - Compulsory Elective Modules**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Fundamentals of Nano Optics                  |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1520430                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                            | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                      | Module owner      | Prof. Dr. Stefanie Kroker                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| 1. Basic concepts (photonic crystals, plasmonics)<br>2. Production and characterisation (metrology) of nano structures<br>3. Photonic nano materials / meta materials / meta surfaces<br>4. Optic nano emitters and nano antennae<br>5. Active photonic elements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| The participants can describe basic phenomena of light propagation (reflection, scattering, absorption, transmission) at interfaces and in homogeneous media qualitatively and quantitatively.<br>Participants can name important basic elements of nanooptics, such as waveguides, optical gratings, photonic crystals or metamaterials, discuss their properties qualitatively and name fields of application.<br>Participants are able to identify the basic elements in complex optical systems and describe their respective functions.<br>The participants can name important processes of micro- and nanostructuring and explain how they work.<br>The participants can solve the wave equation in simple dielectric, metallic and hybrid nanooptical systems analytically and semi-analytically and interpret the solutions.<br>Participants can classify optical resonance phenomena in nanooptical systems and name their essential properties. |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                              |                   |                                                          |
| Novotny, Hecht: Principles of nano-optics, Cambridge University Press 2016<br>Prasad: Nanophotonics, John Wiley & Sons 2004<br>Jahns, Helfert: Introduction to Micro- and Nanooptics, Wiley VCH 2012                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Fundamentals of Nano Optics            | 2,0        | Lecture          | english         |
| Fundamentals of Nano Optics            | 1,0        | Exercise         | english         |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Sensors with Lab                                                                         |                   |                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2411160                                                                                  | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                          | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | only in the summer term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1                                                                                        | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 6 / 8,0                                                                                  | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 240                                                                                      |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 84                                                                                       | Self studying (h) | 156                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                                        |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | oral exam (30 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                          |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                          |                   |                                                                        |
| <ul style="list-style-type: none"><li>- Characteristics of measuring sensors</li><li>- Temperature measurement</li><li>- Magnetic field measurement</li><li>- Optical sensors</li><li>- Measurement of geometric quantities</li><li>- Measurement of dynamometric quantities</li><li>- Flow measurement</li></ul>                                                                                                                                                                                                                                                                                                                                      |                                                                                          |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                                        |
| After completing the module 'Sensors for non-electrical quantities', students will have an overview of the use and dimensioning of electrical sensors for non-electrical quantities. The in-depth fundamentals enable the selection, use and error assessment of modern sensors. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary qualifications are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation, dialogue and presentation techniques as well as teamwork in the laboratory or project. |                                                                                          |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                          |                   |                                                                        |
| <ul style="list-style-type: none"><li>- P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag), ISBN 978-3486225921</li><li>- H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart), ISBN 978-3519061250</li><li>- J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag), ISBN 978-3540622314</li><li>- J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig), ISBN 978-3446219779</li></ul>                                                                                                                                                                                                       |                                                                                          |                   |                                                                        |



|                                                                                                                                                                                                                                                                                       |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                             | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                       | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |
|                                                                                                                                                                                                                                                                                       | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |
|                                                                                                                                                                                                                                                                                       | 3,0        | Laboratory       | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Digital Signal Processing with Microcontrollers with Experiments                         |                   |                                                                        |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2411170                                                                                  | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                          | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the summer term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                                                        | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 5 / 6,0                                                                                  | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 180                                                                                      |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 70                                                                                       | Self studying (h) | 110                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                          |                   |                                                                        |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | oral exam (30 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                          |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                          |                   |                                                                        |
| Statistical treatment of measurement data,<br>Interpolation of measurement data,<br>Signal analysis: discrete (DFT) and fast (FFT) Fourier transformation<br>z-transform: digital filters, correlation, simulation of a closed control loop,<br>Controller and controlled system as IIR and FIR filters.<br>Assembly language of microprocessors<br>Implementation of digital signal processing algorithms in assembler and C                                                                                                                                                                                                                                                             |                                                                                          |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                          |                   |                                                                        |
| After completing the module 'Digital Measurement Data Processing with Microcomputers', students will have an overview of the functionality and programming of microcontrollers for measurement data processing. The acquired practical knowledge enables the programming of embedded systems for metrological applications. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary skills are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation, dialogue and presentation techniques as well as teamwork in the laboratory or project. |                                                                                          |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                                        |
| A multimedia CD-ROM with lecture notes and exercises is offered for the lecture<br>- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984, ISBN 978-3519001416<br>- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985, ISBN 978-3486298451<br>- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979, ISBN 978-3486245288<br>- Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983, ISBN 978-3486244328                                      |                                                                                          |                   |                                                                        |



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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984</li> <li>• Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985</li> <li>• Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979</li> <li>• Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984</li> <li>• Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985</li> <li>• Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979</li> <li>• Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Laser Metrology and Material Processing                                                   |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2413580                                                                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                           | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the summer term                                                                   | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                                                                         | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3 / 5,0                                                                                   | Module owner      | Prof. Dr. Tobias Voß                                     |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                                                                       |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 42                                                                                        | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                           |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | oral exam (30 minutes) or written exam (120 minutes), depending on number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Presentation                                                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                           |                   |                                                          |
| Basic laser technology<br>generation of ultrashort laser pulses<br>characterization of laser beams and laser pulses<br>spectroscopy with sub-nanosecond time resolution<br>basics of nonlinear optics<br>light-matter interaction<br>laser-based material processing of semiconductors<br>modern spectroscopy methods in semiconductor technology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                           |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                           |                   |                                                          |
| Students will be familiar with the functionality of modern laser systems used in the field of semiconductor technology and can explain their mode of operation based on theoretical models. They can describe the interaction of laser light with matter theoretically. They analyze optical emission spectra (luminescence, plasma, Raman scattering, time-resolved signals) and can draw conclusions about material and interaction processes. They know the basic processes of laser material processing, especially with modern ultrashort pulse lasers. They can describe nonlinear optical processes theoretically and understand their significance for laser-based methods in semiconductor technology. They record optical spectra from laser-based processes under guidance and independently prepare a scientific evaluation and interpretation, which they present in a short presentation. |                                                                                           |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                           |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                           |                   |                                                          |

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|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 1,0        | Exercise         | german          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                  |                   |                                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-------------------|--------------------------------------------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Microwave and Wireless Metrology |                   |                                                                                                  |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2424530                          | Module version    |                                                                                                  |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                  | Language          | german                                                                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the winter term          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik                                         |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze<br>Institut für Nachrichtentechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 4 / 5,0                          | Module owner      | Prof. Dr. Thomas Kürner                                                                          |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                              |                   |                                                                                                  |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 56                               | Self studying (h) | 94                                                                                               |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                  |                   |                                                                                                  |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | oral exam (30 min)               |                   |                                                                                                  |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                  |                   |                                                                                                  |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                  |                   |                                                                                                  |
| <ul style="list-style-type: none"><li>- Introduction to metrology</li><li>- Fundamentals of high-frequency technology</li><li>- Measurements in the time domain</li><li>- Spectrum analysis</li><li>- Vector network analysis</li><li>- Antenna measurement technology</li><li>- Channel measurements</li><li>- Protocol measurement technology</li></ul>                                                                                                                                                                                                                  |                                  |                   |                                                                                                  |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                  |                   |                                                                                                  |
| The lecture deals with the basics of modern communication measurement technology. Students will learn about the measurement of signals and transmission characteristics in the time and frequency domain, antenna measurement technology, protocol measurement technology and channel measurement, which are essential for understanding and using state-of-the-art measuring devices, for example in the field of mobile communications. After completing the module, students will be able to use current measurement systems in research and development independently. |                                  |                   |                                                                                                  |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                  |                   |                                                                                                  |
| <ul style="list-style-type: none"><li>- Slides</li><li>- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde &amp; Schwarz, 2004</li><li>- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde &amp; Schwarz, 2007</li><li>- A.Molisch: Wireless Communications, Wiley, 2005</li></ul>                                                                                                                                                                                                                                                                              |                                  |                   |                                                                                                  |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                  |                   |                                                                                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                  |                   |                                                                                                  |



|                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                            | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Foliensammlung</li> <li>- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde &amp; Schwarz, 2004</li> <li>- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde &amp; Schwarz, 2007</li> <li>- A.Molisch: Wireless Communications, Wiley, 2005</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                            | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Foliensammlung</li> <li>- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde &amp; Schwarz, 2004</li> <li>- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde &amp; Schwarz, 2007</li> <li>- A.Molisch: Wireless Communications, Wiley, 2005</li> </ul> |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Gallium Nitride Technology                  |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2413000030                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                     | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| <p>The course builds on ‘Lighting Technology I’. While Lighting Technology I focusses on general questions of lighting and lighting technology, this course discusses LED technology and gallium nitride technology in particular:</p> <ul style="list-style-type: none"><li>• Physical principles of LEDs. Band gap engineering in LEDs.</li><li>• Semiconductor materials for optoelectronics</li><li>• Relationship between material properties and LED properties</li><li>• Manufacturing processes</li><li>• Efficiency considerations</li><li>• Front-end and back-end processing</li><li>• Application examples in general lighting, automotive technology, sensor technology</li><li>• Infrared LEDs, visible light, UV LEDs</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| <p>After completing the module, students will have an overview of the current state of LED technology and the development opportunities that solid state lighting will offer in the future. In addition, they will have a basic understanding of the physical processes within LEDs.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Gallium Nitride Technology             | 2,0        | Lecture          | german          |
| Gallium Nitride Technology             | 1,0        | Exercise         | german          |

**Major Specialisation: Metrology and Measurement Technology - Elective Modules**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Fundamentals of Nano Optics                  |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1520430                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                            | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                      | Module owner      | Prof. Dr. Stefanie Kroker                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| 1. Basic concepts (photonic crystals, plasmonics)<br>2. Production and characterisation (metrology) of nano structures<br>3. Photonic nano materials / meta materials / meta surfaces<br>4. Optic nano emitters and nano antennae<br>5. Active photonic elements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| The participants can describe basic phenomena of light propagation (reflection, scattering, absorption, transmission) at interfaces and in homogeneous media qualitatively and quantitatively.<br>Participants can name important basic elements of nanooptics, such as waveguides, optical gratings, photonic crystals or metamaterials, discuss their properties qualitatively and name fields of application.<br>Participants are able to identify the basic elements in complex optical systems and describe their respective functions.<br>The participants can name important processes of micro- and nanostructuring and explain how they work.<br>The participants can solve the wave equation in simple dielectric, metallic and hybrid nanooptical systems analytically and semi-analytically and interpret the solutions.<br>Participants can classify optical resonance phenomena in nanooptical systems and name their essential properties. |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                              |                   |                                                          |
| Novotny, Hecht: Principles of nano-optics, Cambridge University Press 2016<br>Prasad: Nanophotonics, John Wiley & Sons 2004<br>Jahns, Helfert: Introduction to Micro- and Nanooptics, Wiley VCH 2012                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Fundamentals of Nano Optics            | 2,0        | Lecture          | english         |
| Fundamentals of Nano Optics            | 1,0        | Exercise         | english         |

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| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Gravitational Wave Detection |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1520440                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | only in the winter term      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1                            | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 3 / 5,0                      | Module owner      | Prof. Dr. Stefanie Kroker                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 150                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 42                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | oral exam (30 min)           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                              |                   |                                                          |
| <div>- Gravitational waves and their sources</div> <div>- Historical development of gravitational wave detectors</div> <div>- Interferometric gravitational wave detectors</div> <div>- Noise processes in opto-mechanical systems</div> <div>- Future gravitational wave detectors</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                              |                   |                                                          |
| The participants will be able to describe the origin of gravitational waves phenomenologically, name types of sources and assign typical spectra to them. The participants can name different types of detection of gravitational waves and describe their mode of action qualitatively. The participants can name essential components of an interferometric gravitational wave detector and explain how they work. The participants can name essential fundamental noise processes, explain their respective physical causes and assign frequency ranges in which they limit the sensitivity of gravitational wave detectors. The participants can name advanced interferometer techniques and quantum technologies for increasing sensitivity and explain their mechanisms of action. |                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                              |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                              |                   |                                                          |

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|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Gravitational Wave Detection           | 2,0        | Lecture          | german          |
| Gravitational Wave Detection           | 1,0        | Exercise         | german          |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Sensors with Lab                                                                         |                   |                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2411160                                                                                  | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                          | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | only in the summer term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1                                                                                        | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 6 / 8,0                                                                                  | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 240                                                                                      |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 84                                                                                       | Self studying (h) | 156                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                                        |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | oral exam (30 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                          |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                          |                   |                                                                        |
| <ul style="list-style-type: none"><li>- Characteristics of measuring sensors</li><li>- Temperature measurement</li><li>- Magnetic field measurement</li><li>- Optical sensors</li><li>- Measurement of geometric quantities</li><li>- Measurement of dynamometric quantities</li><li>- Flow measurement</li></ul>                                                                                                                                                                                                                                                                                                                                      |                                                                                          |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                                        |
| After completing the module 'Sensors for non-electrical quantities', students will have an overview of the use and dimensioning of electrical sensors for non-electrical quantities. The in-depth fundamentals enable the selection, use and error assessment of modern sensors. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary qualifications are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation, dialogue and presentation techniques as well as teamwork in the laboratory or project. |                                                                                          |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                          |                   |                                                                        |
| <ul style="list-style-type: none"><li>- P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag), ISBN 978-3486225921</li><li>- H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart), ISBN 978-3519061250</li><li>- J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag), ISBN 978-3540622314</li><li>- J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig), ISBN 978-3446219779</li></ul>                                                                                                                                                                                                       |                                                                                          |                   |                                                                        |



|                                                                                                                                                                                                                                                                                       |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                             | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                       | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |
|                                                                                                                                                                                                                                                                                       | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |
|                                                                                                                                                                                                                                                                                       | 3,0        | Laboratory       | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Digital Signal Processing with Microcontrollers with Experiments                         |                   |                                                                        |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2411170                                                                                  | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                          | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the summer term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                                                        | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 5 / 6,0                                                                                  | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 180                                                                                      |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 70                                                                                       | Self studying (h) | 110                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                          |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | oral exam (30 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                          |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                          |                   |                                                                        |
| Statistical treatment of measurement data,<br>Interpolation of measurement data,<br>Signal analysis: discrete (DFT) and fast (FFT) Fourier transformation<br>z-transform: digital filters, correlation, simulation of a closed control loop,<br>Controller and controlled system as IIR and FIR filters.<br>Assembly language of microprocessors<br>Implementation of digital signal processing algorithms in assembler and C                                                                                                                                                                                                                                                             |                                                                                          |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                          |                   |                                                                        |
| After completing the module 'Digital Measurement Data Processing with Microcomputers', students will have an overview of the functionality and programming of microcontrollers for measurement data processing. The acquired practical knowledge enables the programming of embedded systems for metrological applications. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary skills are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation, dialogue and presentation techniques as well as teamwork in the laboratory or project. |                                                                                          |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                                        |
| A multimedia CD-ROM with lecture notes and exercises is offered for the lecture<br>- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984, ISBN 978-3519001416<br>- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985, ISBN 978-3486298451<br>- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979, ISBN 978-3486245288<br>- Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983, ISBN 978-3486244328                                      |                                                                                          |                   |                                                                        |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984</li> <li>• Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985</li> <li>• Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979</li> <li>• Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984</li> <li>• Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985</li> <li>• Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979</li> <li>• Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983</li> </ul> |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                        |                   |                                                                        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Bioanalysis                                                                            |                   |                                                                        |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2411180                                                                                | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                        | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the winter term                                                                | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1                                                                                      | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 5 / 6,0                                                                                | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 180                                                                                    |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 70                                                                                     | Self studying (h) | 110                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                        |                   |                                                                        |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Oral exam (30 min); written exam (120 min) only in case of high number of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                        |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                        |                   |                                                                        |
| <ul style="list-style-type: none"><li>- Cell: Structure and cell division</li><li>- Cell nucleus and chromosomes</li><li>- Genetic code</li><li>- From DNA to protein</li><li>- Electrochemical basics</li><li>- Separation methods</li><li>- Cell disruption and PCR</li><li>- NMR spectroscopy</li><li>- Optical spectroscopy</li><li>- Microscopy</li><li>- Marker-based analysis methods</li><li>- Functional analysis</li><li>- Biochips / Lab on a Chip</li><li>- Immune system</li></ul>                                                                                                                      |                                                                                        |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                        |                   |                                                                        |
| After completing the "Bioanalytics" module, students will have an overview of analytical procedures in molecular biology and biochemistry. The practical knowledge they have acquired enables them to carry out and interpret simple analyses. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary qualifications are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation, dialogue and presentation techniques as well as teamwork in the laboratory or project. |                                                                                        |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                        |                   |                                                                        |
| A multimedia-CD-ROM with script and exercises is offered for the lecture <ul style="list-style-type: none"><li>- M. Madigan et al., Brock - Mikrobiologie, Spektrum Akad. Verlag, ISBN 978-3827405661</li><li>- G.M. Cooper, R. E. Hausman, The Cell, ASM Press / Sinauer Assoc. Sunderland MA, ISBN 978-0878932207</li><li>- Hans Naumer und Wolfgang Heller (Hrsg.), Untersuchungsmethoden in der Chemie, Georg Thieme Verlag, Stuttgart, 1990, ISBN 978-3136814031</li></ul>                                                                                                                                      |                                                                                        |                   |                                                                        |

- F. Lottspeich/H. Zorbas, Bioanalytik, Spektrum Akademischer Verlag Heidelberg 1998, ISBN 978-3827400413

**Remark**

Mainly for Master's students.



**Related courses**

**Rules for the choice of courses**

**Compulsory attendance**

| Name of the course | SWS | Eventtype | Language |
|--------------------|-----|-----------|----------|
|--------------------|-----|-----------|----------|

|  |     |         |        |
|--|-----|---------|--------|
|  | 2,0 | Lecture | german |
|--|-----|---------|--------|

**Literature**

- M. Madigan et al. Brock - Mikrobiologie, Spektrum Akad. Verlag
- G.M. Cooper, R. E. Hausman, The Cell, ASM Press / Sinauer Assoc. Sunderland MA
- Hans Naumer und Wolfgang Heller (Hrsg.), Untersuchungsmethoden in der Chemie, Georg Thieme Verlag, Stuttgart, 1990
- F. Lottspeich/H. Zorbas Bioanalytik, Spektrum Akademischer Verlag Heidelberg 1998

|  |     |          |        |
|--|-----|----------|--------|
|  | 1,0 | Exercise | german |
|--|-----|----------|--------|

**Literature**

- M. Madigan et al. Brock - Mikrobiologie, Spektrum Akad. Verlag
- G.M. Cooper, R. E. Hausman, The Cell, ASM Press / Sinauer Assoc. Sunderland MA
- Hans Naumer und Wolfgang Heller (Hrsg.), Untersuchungsmethoden in der Chemie, Georg Thieme Verlag, Stuttgart, 1990
- F. Lottspeich/H. Zorbas Bioanalytik, Spektrum Akademischer Verlag Heidelberg 1998

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Biomedical Engineering with Experiments                                                 |                   |                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2411190                                                                                 | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                         | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                                                                 | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                                                       | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 5 / 6,0                                                                                 | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 180                                                                                     |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 70                                                                                      | Self studying (h) | 110                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                         |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Oral exam (30 min); written exam (120 min) only in case of high numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                         |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                         |                   |                                                                        |
| <ul style="list-style-type: none"><li>- Introduction to biomedical technology</li><li>- Physiological systems and biomedical parameters</li><li>- Development of cell potentials</li><li>- Measurement of potentials in the cell</li><li>- Electrocardiogram (ECG)</li><li>- Electroencephalography (EEG)</li><li>- Electromyography (EMG)</li><li>- Biomagnetic signals</li><li>- Cardiovascular diagnostics</li><li>- Pulmonary function diagnostics</li><li>- Pulse oximetry</li><li>- Ultrasound diagnostics</li><li>- X-ray diagnostics and computer tomography (CT)</li><li>- Magnetic resonance imaging (MRI)</li></ul> |                                                                                         |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                         |                   |                                                                        |
| <p>After completing the "Biomedical Engineering" module, students will have an overview of the most important diagnostic procedures in human medicine. The practical knowledge acquired enables the design and evaluation of simple diagnostic procedures.</p> <p>In accordance with the didactic concept of the course, the knowledge acquired in the lecture is put into practice in laboratory experiments after an introductory colloquium in teamwork. Students will also practise scientific writing and documentation in an experimental protocol.</p>                                                                  |                                                                                         |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                         |                   |                                                                        |
| <p>A multimedia-CD-ROM with script and exercises is offered for the lecture</p> <ul style="list-style-type: none"><li>- J. J. Carr , J.M. Brown, Introduction to Biomedical Equipment Technology, Prentice Hall, 4th ed., Upper Saddle River 2001, ISBN 978-8177588835</li><li>- J. L. Prince, J. M. Links , Medical Imaging: Signals and Systems, Pearson/Prentice Hall, 1st ed., Upper Saddle River 2006. ISBN 978-0130653536</li></ul>                                                                                                                                                                                      |                                                                                         |                   |                                                                        |

- J. Eichmeier, Medizinische Elektronik, Springer Verlag, 3. Auflage Berlin 1997, ISBN 978-0387533872



|                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                    | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                              | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <ul style="list-style-type: none"> <li>• J. J. Carr , J. M. Brown, Introduction to Biomedical Equipment Technology, Prentice Hall, 4th ed., Upper Saddle River 200#</li> <li>• J. L. Prince, J. M. Links, Medical Imaging: Signals and Systems, Pearson/Prentice Hall, 1st ed., Upper Saddle River 2006</li> <li>• J. Eichmeier, Medizinische Elektronik, Springer Verlag, 3. Auflage Berlin 1997</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                              | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <ul style="list-style-type: none"> <li>• J. J. Carr , J. M. Brown, Introduction to Biomedical Equipment Technology, Prentice Hall, 4th ed., Upper Saddle River 200#</li> <li>• J. L. Prince, J. M. Links, Medical Imaging: Signals and Systems, Pearson/Prentice Hall, 1st ed., Upper Saddle River 2006</li> <li>• J. Eichmeier, Medizinische Elektronik, Springer Verlag, 3. Auflage Berlin 1997</li> </ul> |            |                  |                 |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Nanoelectronics                                                                   |                   |                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2411200                                                                           | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                   | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the summer term                                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                                                 | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4 / 5,0                                                                           | Module owner      | Prof. Dr. Oleksandr Dobrovolskiy                                       |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                                                               |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 56                                                                                | Self studying (h) | 94                                                                     |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                   |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Oral exam (30 min), written exam (120 min) only for a high number of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                   |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                   |                   |                                                                        |
| <ul style="list-style-type: none"><li>• Quantum mechanics Wave function, potentials, interaction</li><li>• Magnetism</li><li>• Superconductivity</li><li>• Manufacturing processes</li><li>• Josephson junctions</li><li>• SET components</li><li>• Data memory</li><li>• THz transistors</li><li>• Quantum computing</li></ul>                                                                                                                                                                                                                                                                                                                                                |                                                                                   |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                   |                   |                                                                        |
| After completing the module 'Nanoelectronics', students will have an overview of the fundamentals of quantum mechanics and its application to metallic, magnetic and superconducting components with nanometre dimensions.                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                   |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                   |                   |                                                                        |
| A multi-media CD ROM with script and exercises is available for the lecture<br>- R. Waser, #Nanoelectronics and Information Technology#, Wiley-VCH, 2003, ISBN 978-3527403639<br>- M. Köhler, #Nanotechnologie#, Wiley-VCH, 2007, ISBN 978-3527318711<br>- Jasprit Singh, #Modern Physics for Engineers#, Wiley, 1999, ISBN 978-0471330448<br>- N. Ashcroft, N. Mermin, #Solid State Physics#, Cengage Learning Services, 1976, ISBN 978-0030839931<br>- S. Flügge, #Rechenmethoden der Quantentheorie#, Springer Verlag 1993, ISBN 978-3540567769<br>- W. Nolting, #Quantenmechanik#, Band 5 aus #Grundkurs: Theoretische Physik#, Springer-Verlag, 2007, ISBN 978-3540688686 |                                                                                   |                   |                                                                        |



|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Nanoelectronics                                                                                                                                                                                                                                                                                                                                                                                                                     | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <ul style="list-style-type: none"> <li>• R. Waser, Nanoelectronics and Information Technology, Wiley-VCH</li> <li>• M. Köhler, Nanotechnologie, Wiley-VCH</li> <li>• Jasprit Singh, Modern Physics for Engineers, Wiley</li> <li>• N. Ashcroft, N. Mermin, Solid State Physics</li> <li>• S. Flügge, Rechenmethoden der Quantentheorie</li> <li>• W. Nolting, Quantenmechanik, Band 5 aus Grundkurs: Theoretische Physik</li> </ul> |            |                  |                 |
| Nanoelectronics                                                                                                                                                                                                                                                                                                                                                                                                                     | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <ul style="list-style-type: none"> <li>• R. Waser, Nanoelectronics and Information Technology, Wiley-VCH</li> <li>• M. Köhler, Nanotechnologie, Wiley-VCH</li> <li>• Jasprit Singh, Modern Physics for Engineers, Wiley</li> <li>• N. Ashcroft, N. Mermin, Solid State Physics</li> <li>• S. Flügge, Rechenmethoden der Quantentheorie</li> <li>• W. Nolting, Quantenmechanik, Band 5 aus Grundkurs: Theoretische Physik</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Precision Measuring Techniques                                                           |                   |                                                                        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2411210                                                                                  | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                          | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                                                                        | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                                                                                  | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                                                                                      |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                                                                                       | Self studying (h) | 94                                                                     |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                          |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | oral exam (30 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                          |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                          |                   |                                                                        |
| <ul style="list-style-type: none"><li>- Measuring at physical limits</li><li>- Fundamentals of quantum effects and construction of precision devices</li><li>- Electrical and magnetic properties of Josephson elements,</li><li>- SQUIDs (Superconducting Quantum Interference Devices), SETs (Single Electron Tunnelling),</li><li>- Cryogenic current comparators and quantised resistors</li><li>- Accurate DC and AC voltage sources</li><li>- Measurement of small electrical voltages, currents, charges and magnetic fields</li><li>- Application examples in medicine, research and industry.</li></ul> |                                                                                          |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                          |                   |                                                                        |
| After completing the 'Precision Metrology' module, students will have an overview of the fundamentals of precision metrology and primary standards at PTB and metrology in Germany. Through a field trip to the PTB, students learn about the structure of primary standards and the dissemination of SI units. The students are able to apply this knowledge in the analysis and design of measurement and sensor systems.                                                                                                                                                                                      |                                                                                          |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                          |                   |                                                                        |
| V. Kose, F. Melchert "Quantenmaße in der elektrischen Messtechnik", VCH 1991, ISBN 3-527-28380-3<br>J. Hoffmann "Handbuch der Messtechnik", Hanser Verlag 2004, ISBN 3-446-21123-3<br>F. Kohlrausch "Praktische Physik" Teubner Verlag 1996, ISBN 3-519-23000-3<br>K. Kopitzki "Einführung in die Festkörperphysik" Teubner-Verlag 2007, ISBN 3-835-10144-7<br>W. Buckel und R. Kleiner "Supraleitung", Wiley-VCH Verlag, Weinheim, 2004, ISBN 3-527-40348-5<br>Further literature will be announced during the lecture                                                                                          |                                                                                          |                   |                                                                        |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                          |                   |                                                                        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                          |                   |                                                                        |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
| <b>Literature</b>                      |            |                  |                 |
| Wird in der Vorlesung bekannt gegeben  |            |                  |                 |
|                                        | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Quality Assurance and Optimization                                                          |                   |                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2411220                                                                                     | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                             | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | only in the winter term                                                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1                                                                                           | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 4 / 5,0                                                                                     | Module owner      | Prof. Dr. Oleksandr Dobrovolskiy                                       |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 150                                                                                         |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 56                                                                                          | Self studying (h) | 94                                                                     |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                             |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Written exam (45 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                             |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                             |                   |                                                                        |
| Introduction to the measurement process<br>Systematic and random measurement uncertainties/errors Noise and noise analysis<br>Determination of measurement uncertainty according to GUM<br>Fundamentals of applied statistics: distribution functions, estimation theory, hypothesis tests, error propagation<br>Equalisation calculation, regression analysis<br>Statistical design of experiments<br>Quality management                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                             |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                             |                   |                                                                        |
| After completing the module, students will have an overview of the fundamentals of quality management and process optimisation. Thanks to the practical knowledge acquired, students will be able to solve simple optimisation tasks using statistical design of experiments.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                             |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                             |                   |                                                                        |
| - E. Schrüfer: Elektrische Messtechnik (Hanser Verlag 2007), ISBN 978-3446409040<br>- W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall 1991), ISBN 978-0023805523<br>- O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag 1978), ISBN 978-3411001194<br>- N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons 1977), ISBN 978-0471017561 und 978-0471017578<br>- Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig 1974, im Bibliotheksbestand<br>- B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH, 2004), ISBN 978-3833010392<br>- G. Linß: Qualitätsmanagement für Ingenieure (Hanser Fachbuchverlag Leipzig 2005), ISBN 978-3446228214 |                                                                                             |                   |                                                                        |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <ul style="list-style-type: none"> <li>• E. Schrüfer: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall)</li> <li>• O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag)</li> <li>• N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley &amp; Sons)</li> <li>• Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig</li> <li>• B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH)</li> <li>• G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <ul style="list-style-type: none"> <li>• E. Schrüfer: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall)</li> <li>• O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag)</li> <li>• N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley &amp; Sons)</li> <li>• Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig</li> <li>• B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH)</li> <li>• G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Basics of Medicine for Engineers |                   |                                                                        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2411280                          | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                  | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the summer term          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 3 / 5,0                          | Module owner      | Dr. Andreas Höft                                                       |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                              |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 42                               | Self studying (h) | 108                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                  |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Written exam (90 min)            |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                  |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                  |                   |                                                                        |
| <ul style="list-style-type: none"><li>• Introduction</li><li>• Cardiac anatomy, circulation</li><li>• Lungs, breathing, ventilation, endoscopy, bronchoscopy</li><li>• Heart-lung machine, circulatory support, artificial hearts</li><li>• Heart rhythm / cardiac arrhythmias</li><li>• Coronary anatomy, myocardial infarction (diagnosis and therapy), resuscitation</li><li>• Pacemakers, cardiac arrhythmias</li><li>• Surgical techniques</li><li>• Monitoring and intensive care</li><li>• Legal aspects of medical treatment</li><li>• Repetition</li></ul> |                                  |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                  |                   |                                                                        |
| After completing the module “Fundamentals of Medicine for Engineers”, students have a basic overview of human physiology and the use of medical diagnostic procedures. These basics enable them to understand medical diagnostic procedures.                                                                                                                                                                                                                                                                                                                        |                                  |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                  |                   |                                                                        |
| Lecture notes and slides available as downloads on institue website.<br><br>- Schäffler A, Mencke N: Mensch Körper Krankheit, #Anatomie, Physiologie, Krankheitsbilder, Lehrbuch und Atlas für die Berufe im Gesundheitswesen#, Urban & Fischer, München Jena 1999, ISBN 978-3437550911                                                                                                                                                                                                                                                                             |                                  |                   |                                                                        |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                  |                   |                                                                        |
| Max. number of participants is 150. Order of registration decides on participation, no waiting lists. Students with the course as a compulsory elective subject are preferred.<br>Registration starts in March on institute website.                                                                                                                                                                                                                                                                                                                                |                                  |                   |                                                                        |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <p>Zur Vorlesung wird eine Multimedia-CD-ROM mit Skript und Übungen angeboten, zusätzlich zum Download auf der Homepage des Instituts</p> <ul style="list-style-type: none"> <li>- Schäffler A, Mencke N: Mensch Körper Krankheit, Anatomie, Physiologie, Krankheitsbilder Lehrbuch und Atlas für die Berufe im Gesundheitswesem, Urban &amp; Fischer, München Jena 1999</li> <li>- Kramme R, Medizintechnik: Verfahren, Systeme, Informationsverarbeitung Springer, Berlin Heidelberg New York</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <p>Zur Vorlesung wird eine Multimedia-CD-ROM mit Skript und Übungen angeboten, zusätzlich zum Download auf der Homepage des Instituts</p> <ul style="list-style-type: none"> <li>- Schäffler A, Mencke N: Mensch Körper Krankheit, Anatomie, Physiologie, Krankheitsbilder Lehrbuch und Atlas für die Berufe im Gesundheitswesem, Urban &amp; Fischer, München Jena 1999</li> <li>- Kramme R, Medizintechnik: Verfahren, Systeme, Informationsverarbeitung Springer, Berlin Heidelberg New York</li> </ul> |            |                  |                 |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                   |                   |                                                                        |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Measurement Electronics with Experiments                                          |                   |                                                                        |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2411330                                                                           | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                   | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | only in the winter term                                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1                                                                                 | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 6 / 8,0                                                                           | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 240                                                                               |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 84                                                                                | Self studying (h) | 156                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                   |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Oral exam (30 min), written exam (120 min) only for a high number of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Successful participation in lab work                                              |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                   |                   |                                                                        |
| <p>Measuring amplifiers with transistors and OPVs</p> <ul style="list-style-type: none"><li>- Electronic switches</li><li>- Source circuits</li><li>- Measuring transducers</li><li>- Analogue filter circuits</li><li>- Treatment of interference signals and noise</li><li>- Correlation analysis</li><li>- Measurement converters (A/D and D/A)</li><li>- Measuring device buses</li><li>- Time measurement</li><li>- Oscilloscopes and trigger circuits</li></ul> <p>and</p> <p>carrying out experiments in the following areas</p> <ul style="list-style-type: none"><li>- Electronically controllable switches</li><li>- Reference sources for voltages and currents</li><li>- Measuring amplifiers</li><li>- Analogue-to-digital/digital-to-analogue converters</li><li>- Time and frequency measurement</li><li>- Oscilloscope</li><li>- Correlator</li></ul> |                                                                                   |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                   |                   |                                                                        |
| After completing the module 'Measurement Electronics with Practice', students will have an overview of the circuit technology and measurement methods of measurement electronics. The practical knowledge they have acquired enables them to set up circuits for measurement applications. In-depth practical experience with measurement methods that are dealt with in the measurement electronics lecture is taught in the laboratory. In accordance with the didactic concept of the course and the design of the individual components.                                                                                                                                                                                                                                                                                                                          |                                                                                   |                   |                                                                        |

interdisciplinary skills are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation

### Literature

A multi-media CD ROM with script and exercises is available for the lecture

- Allan R. Hambley #Electronics#, Prentice Hall, ISBN 978-0136919827
- U. Tietze, Ch. Schenk #Halbleiter-Schaltungstechnik#, Springer-Verlag, 2002, ISBN 978-3540641926
- Dieter Nührmann #Das komplette Werkbuch Elektronik#, Franzis-Verlag, ISBN 978-3772365263
- P. Horowitz #The Art of Electronics#, Cambridge Univ. Press, ISBN 978-0521689175
- Rupert Patzelt, Herbert Schweinzer, #Elektrische Messtechnik#, Springer Verlag 1996, ISBN 978-3211828731



### Related courses

#### Rules for the choice of courses

#### Compulsory attendance

| Name of the course | SWS | Eventtype | Language |
|--------------------|-----|-----------|----------|
|--------------------|-----|-----------|----------|

|                         |     |         |        |
|-------------------------|-----|---------|--------|
| Measurement Electronics | 2,0 | Lecture | german |
|-------------------------|-----|---------|--------|

#### Literature

- Allan R. Hambley #Electronics, Prentice Hall
- U. Tietze, Ch. Schenk Halbleiter-Schaltungstechnik, Springer-Verlag, 2002
- Dieter Nührmann Das komplette Werkbuch Elektronik, Franzis-Verlag
- P. Horowitz The Art of Electronics, Cambridge Univ. Press
- Rupert Patzelt, Herbert Schweinzer #Elektrische Messtechnik, Springer Verlag 1996

|                         |     |          |        |
|-------------------------|-----|----------|--------|
| Measurement Electronics | 1,0 | Exercise | german |
|-------------------------|-----|----------|--------|

#### Literature

- Allan R. Hambley #Electronics, Prentice Hall
- U. Tietze, Ch. Schenk Halbleiter-Schaltungstechnik, Springer-Verlag, 2002
- Dieter Nührmann Das komplette Werkbuch Elektronik, Franzis-Verlag
- P. Horowitz The Art of Electronics, Cambridge Univ. Press
- Rupert Patzelt, Herbert Schweinzer #Elektrische Messtechnik, Springer Verlag 1996

|                                    |     |            |        |
|------------------------------------|-----|------------|--------|
| Electronics measurement internship | 3,0 | Internship | german |
|------------------------------------|-----|------------|--------|

#### Literature

Internship script

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Additive Manufacturing (3D-Printing)         |                   |                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2411340                                      | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | irregular                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                            | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4 / 5,0                                      | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                          |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 42                                           | Self studying (h) | 108                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | oral exam (30 min) or written exam (120 min) |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                                        |
| <p>Printing Processes<br/>Design with CAD<br/>Slicer<br/>G-Code<br/>Print parameters<br/>Printer electronics and sensors<br/>Printing materials<br/>Printing errors<br/>Post-treatment<br/>Applications</p> <p>After an introduction to computer-aided design (CAD) and introductions to the 3D printers available at the institute, project work is handed out in the tutorial. As part of this project work, students design components for a given task and then produce them on the 3D printers available at the institute. The results are presented by the group at the end of the exercise as part of a presentation.<br/>presented by the group.</p> |                                              |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                                        |
| <p>After completing the module, students will have an overview of the most important additive manufacturing processes. They know the most important components of various printing systems, have mastered the basics of programming these systems and have an overview of usable materials. On completion of the exercise, they will have mastered the basics of design using computer-aided design (CAD) so that they can design components that are produced on the printers available at the institute. They are able to select a suitable printing process for a problem, generate print data and assess the print results.</p>                          |                                              |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                                        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |                   |                                                                        |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
| <b>Literature</b>                      |            |                  |                 |
| -                                      |            |                  |                 |
|                                        | 2,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Identification of Dynamic Systems                   |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2412380                                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                     | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                            | only in the summer term                             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1                                                   | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                         | 4 / 5,0                                             | Module owner      | Marcus Grobe                                             |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 150                                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                          | 56                                                  | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                       | Lecture "Fundamentals of Control Engineering"       |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                  | oral exam (30 minutes) or written exam (60 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                     |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                     |                   |                                                          |
| Statistical basics, closed-loop identification, excitation signals for identification, least square method, bias-free estimation, method of instrumental variables, Box-Jenkins, maximum likelihood method, Cor-LS method.                                                                                                                                                                                                                                    |                                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                     |                   |                                                          |
| After completing the module, students will be able to determine model parameters for linear systems using statistical methods (identification) and evaluate algorithms for their determination.                                                                                                                                                                                                                                                               |                                                     |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                     |                   |                                                          |
| <div>- E. Hänsler: Statistische Signale</div> <div>- Grundlagen und Anwendungen, Springer-Verlag, ISBN: 978-3540416449</div> <div>- R. Isermann: Identifikation dynamischer Systeme I &amp; II, Springer-Verlag, ISBN: 978-3540549246 &amp; 978-3540554684</div> <div>- L. Ljung: System Identification, Prentice Hall, ISBN: 978-0136566953</div> <div>- W. Leonhard: Statistische Analyse linearer Regelsysteme, Teubner-Verlag, ISBN: 978-3519020462</div> |                                                     |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|  |     |          |        |
|--|-----|----------|--------|
|  | 2,0 | Lecture  | german |
|  | 2,0 | Exercise | german |

|                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                              |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                     | Data Bus Systems                                                                             |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2412400                                                                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the winter term                                                                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                                                            | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                                                                      | Module owner      | Prof. Dr. Markus Maurer                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                                                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                                                                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                              |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                              | oral exam (30 minutes) or written exam (60 minutes), depending on the number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                              |                   |                                                          |
| <div>- Bus architectures and access methods</div> <div>- Physical layers</div> <div>- Network and transport layer according to ISO layer model using the example of the OSEK standard for Network communication and management</div> <div>- LIN, CAN, TTP, FlexRay, MOST and Bluetooth</div> <div>- Interbus, Profibus, HART, ASI</div> <div>- Procedure for the selection of a suitable data bus system for a selected application</div> |                                                                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                              |                   |                                                          |
| After completing this module, students have basic knowledge of architectures and protocol standards of data bus systems in modern motor vehicles as well as industrial plants. They are familiar with functional principles and properties of commonly used data buses from various application areas. The fundamentals learned enable them to independently design or analyze and evaluate networked systems.                            |                                                                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                              |                   |                                                          |
| <div>- Zimmermann, Schmidgall, Bussysteme in der Fahrzeugtechnik, Vieweg Verlag 2006, ISBN 3-8348-0166-6</div> <div>- G. Schnell, B. Wiedemann, Bussysteme in der Automatisierungs- und Prozesstechnik, Vieweg Verlag 2006, ISBN 3-8348-0045-7</div>                                                                                                                                                                                      |                                                                                              |                   |                                                          |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| both lectures and exercises must be attended                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Foliensammlung</li> <li>- Literaturempfehlungen in der Vorlesung</li> <li>- Etschberger, Controller-Area-Network, Hanser Verlag</li> <li>- Grzempa: LIN-Bus, Franzis Verlag</li> <li>- Rausch: Flexray, Hanser Verlag</li> <li>- Schäuffele: Automotive Software Engineering, Vieweg Verlag</li> <li>- Zimmermann: Bussysteme in der Fahrzeugtechnik, Vieweg Verlag</li> <li>- Schnell, Wiedemann: Bussysteme in der Automatisierungs- und Prozesstechnik</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1,0        | Exercise         | german          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                       |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Nonlinear Control Systems                                                             |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2412670                                                                               | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                       | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term                                                               | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                                                                     | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4 / 5,0                                                                               | Module owner      | Marcus Grobe                                             |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                                                                   |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 56                                                                                    | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                       |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Written exam 60 minutes or oral exam 30 minutes (depending on number of participants) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                       |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                       |                   |                                                          |
| Fundamentals and application of nonlinear control theory, Lyapunov stability theory, exact linearization, Sliding mode control, method of the description function for non-linear systems (harmonic linearization)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                       |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                       |                   |                                                          |
| <p>After completing the module, students will be able to describe non-linear systems in the form of differential equations.</p> <p>With the help of Lyapunov's stability theory, students are able to describe the rest positions of non-linear systems and assess their stability.</p> <p>The learned method of exact linearization enables students to apply known methods of linear controller design to non-linear systems with affine input. Exact linearization compensates for the non-linearities present in the system using a nonlinearities present in the system by means of a feedback law and thus allows the design of a linear controller.</p> <p>Using the method of sliding-mode control, students are enabled to design switching controllers based on state-dependent switching between different control laws and to evaluate them with regard to the limit cycles that occur.</p> <p>limit cycles.</p> <p>In addition, using the harmonic balance method, students acquire the ability to analyze oscillations and limit cycles in non-linear systems and to make statements as to whether these oscillations will actually occur.</p> |                                                                                       |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                       |                   |                                                          |
| Jürgen Adamy: Nichtlineare Regelungen. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009<br>Jean-Jaques E. Slotine; Weiping Li: Applied nonlinear control, Englewood Cliffs, NJ: Prentice Hall, 1991                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                       |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                       |                   |                                                          |
| Requirement: Lecture "Fundamentals of Control Engineering" and "Advanced Control Engineering"                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Semiconductor Metrology |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2413330                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                         | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the summer term | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                       | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 3 / 5,0                 | Module owner      | Prof. Dr. Erwin Peiner                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 42                      | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                         |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | oral exam (30 min)      |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |                   |                                                          |
| <ul style="list-style-type: none"><li>- Crystal-structure analysis, X-ray diffraction</li><li>- Lattice defects</li><li>- Epitaxial layers, nanostructures, lattice mismatch</li><li>- Microscopy (light, electrons, scanning probes), imaging modes, analytical electron microscopy</li><li>- Band structure, band gap, excitation spectroscopy, spatially resolved luminescence, effective mass</li><li>- Electrical transport properties, piezoresistive effect</li><li>- Charge carrier concentration and mobility, Hall method, CV method</li><li>- Optical absorption, Fourier transform spectroscopy</li><li>- Impurities and defects, chemical analysis, deep traps</li><li>- Minority carrier lifetime, diffusion length</li><li>- Metal-semiconductor junction, Schottky contact, Ohmic contact, sheet resistance</li><li>- Oxide layers, ellipsometry</li><li>- Device characteristics</li></ul> |                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                         |                   |                                                          |
| After completing the module semiconductor characterization, the students will have <ul style="list-style-type: none"><li>- a basic understanding of the most important methods for characterizing semiconductor materials</li><li>- the ability to select appropriate quality control procedures in the manufacture of semiconductor devices</li><li>- in-depth knowledge and practical experience in the analysis and evaluation of measurement results with bulk crystals, layers as well as micro- and nanostructured devices</li></ul>                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |
| K. Kopitzki: Einführung in die Festkörperphysik (Teubner, Stuttgart, 1989) ISBN: 3-519-13083-1<br>H. Alexander: Physikalische Grundlagen der Elektronenmikroskopie (Teubner, Stuttgart, 1997) ISBN: 3-519-03221-X<br>W. Prost: Technologie der III/V-Halbleiter: III/V-Heterostrukturen und elektronische Höchstfrequenz-Bauelemente (Springer, Berlin, 1997) ISBN:3-540-62804-5<br>W. Schäfer, G. Terlecki: Halbleiterprüfung (Hüthig, Heidelberg, 1986) ISBN: 3-778-51007-X                                                                                                                                                                                                                                                                                                                                                                                                                               |                         |                   |                                                          |

D. K. Schroder: Semiconductor Material and Device Characterization (Wiley, New York, 1990) ISBN: 0-471-51104-8  
 R. Wiesendanger (Hrsg): Scanning Probe Microscopy - Analytical Methods (Springer, Berlin, 1998) ISBN: 3-540-63815-6  
 Script and exercise materials will be handed out.



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| K. Kopitzki: Einführung in die Festkörperphysik (Teubner, Stuttgart, 1989)<br>H. Alexander: Physikalische Grundlagen der Elektronenmikroskopie (Teubner, Stuttgart, 1997)<br>W. Prost: Technologie der III/V-Halbleiter: III/V-Heterostrukturen und elektronische Höchstfrequenz-Bauelemente (Springer, Berlin, 1997)<br>W. Schäfer, G. Terlecki: Halbleiterprüfung (Hüthig, Heidelberg, 1986)<br>D. K. Schroder: Semiconductor Material and Device Characterization (Wiley, New York, 1990)<br>R. Wiesendanger (Hrsg): Scanning Probe Microscopy - Analytical Methods (Springer, Berlin, 1998) |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| Übungsunterlagen und Vorlesungsskript werden verteilt.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Semiconductor Sensors   |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2413340                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                         | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the winter term | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                       | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                 | Module owner      | Prof. Dr. Erwin Peiner                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                      | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                         |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | oral exam (30 min)      |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |
| <div>- Elementary sensors: periodic excitation, mass, damping coefficient, spring constant, accelerometer, noise, vibration sensor, yaw rate sensor, bending stiffness/force sensor/transfer standard, Film Stress/Thermal Sensor, Diaphragm/Pressure/Flow Sensor, Overload Resistance/Impact Sensor</div> <div>- Transducers: pressure sensor (capacitive/optical transducer), acceleration sensor (capacitive transducer), Acceleration Sensor (piezoelectric transducer), vibration sensor/acceleration sensor (optical transducer), force sensor (piezoresistive transducer), vibration sensor (piezoresistive transducer, piezoresistive sensor with fiber optic readout), yaw rate sensor (drive and detection), acceleration sensor (tunnel-effect transducer), comparison and rating</div> <div>- Surface micromachining: diffusion, oxidation, layer deposition, lithography, wet/dry etching, sticking, integration with CMOS</div> <div>- Volume micromachining: implantation/diffusion, metallization (evaporation/cathode sputtering), isotropic/anisotropic etching, electrochemical etching</div> <div>- Epi-micromachining: Epi-poly, conformal deposition, SIMPLE, SCREAM, black silicon, SOI, electrochemical etching, porous silicon, hetero-micromachining, comparison</div> <div>- Condition monitoring: machine tool, sensor/technology, roller bearings, kinematic frequencies, bogie bearing, signal analysis (envelope/resonant), calender roll, EMC/ fiber-optic readout, cavitation</div> <div>- Engine management: combustion process, combustion engine efficiency, cylinder pressure indexing, average indicated pressure pmi, cylinder filling, heating process, engine control with adaptive pre-control, sensors</div> <div>- Micro/nano metrology</div> |                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                         |                   |                                                          |
| <div>After completing the module semiconductor sensors, the students will have</div> <div>- a basic understanding of the most important methods for modelling, fabrication and characterization of micro-/nano-mechanical semiconductor sensors</div> <div>- the ability to select suitable manufacturing processes for the realization of micro- and nano-structured semiconductor sensors</div> <div>- in-depth knowledge and practical experience in designing sensors</div> <div>- knowledge for assessing and evaluating possible uses of micro-/nano-mechanical sensors</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                         |                   |                                                          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <p>A. Heuberger (Hrsg): Mikromechanik (Springer, Berlin, 1989) ISBN: 3-540-18721-9</p> <p>M.-H. Bao: Handbook of Sensors and Actuators 8 - Micro Mechanical Transducers (Elsevier, Amsterdam, 2000) ISBN 0-444-50558-X S. Büttgenbach: Mikromechanik (Teubner, Stuttgart, 1994) ISBN: 3-519-13071-8</p> <p>M. Elwenspoek, R. Wiegerink: Mechanical Microsensors (Springer, Berlin, 2001) ISBN: 3-540-67582-5</p> <p>E. Peiner: Silizium-Sensorik für die Maschinenüberwachung (Shaker, Aachen 2000) ISBN: 3-8265-7401-X</p> <p>Skript und Übungsunterlagen werden verteilt.</p> |



|                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                     | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <p>A. Heuberger (Hrsg): Mikromechanik (Springer, Berlin, 1989) M.-H. Bao: Handbook of Sensors and Actuators 8 - Micro Mechanical Transducers (Elsevier, Amsterdam, 2000) S. Büttgenbach: Mikromechanik (Teubner, Stuttgart, 1994) M. Elwenspoek, R. Wiegerink: Mechanical Microsensors (Springer, Berlin, 2001)</p> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                     | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| Übungsunterlagen und Vorlesungsskript werden verteilt.                                                                                                                                                                                                                                                              |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                           |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Nano- and Bioelectronic System                                                            |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2413560                                                                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                           | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | only in the winter term                                                                   | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                                                                         | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 3 / 5,0                                                                                   | Module owner      | Prof. Dr. Tobias Voß                                     |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 150                                                                                       |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 42                                                                                        | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                           |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Oral exam (30 minutes) or written exam (120 minutes), depending on number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                           |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                           |                   |                                                          |
| Introduction to nanotechnology<br>growth, nanostructuring and characterization processes and tools (lithography, microscopy, raster probe technique, spectroscopy, nanotubes, nanowires, nanoparticles, hybrid nanostructures<br>bio-organic functionalization of surfaces (Langmuir-Blodgett, self-assembled monolayers on metals and semiconductors)<br>semiconductor nano- and biosensors based on different inorganic and organic nanomaterials<br>hybrid nanostructures for optoelectronics  |                                                                                           |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                           |                   |                                                          |
| After completion of the module Nano- and Bioelectronic Systems, the students possess<br>- a basic understanding of the most important techniques for the preparation and characterization of inorganic and hybrid nanoelectronic systems (nanoparticles, nanotubes, nanowires, quantum well structures)<br>- the ability to combine acquired fundamental knowledge to understand and evaluate advanced semiconductor-based nano and biosensors as well as nanoscale hybrid optoelectronic devices |                                                                                           |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                           |                   |                                                          |
| "Nanoelectronics and Information Technology. Advanced Electronic Materials and Novel Devices", R. Waser (Ed.), Wiley-VCH, 2nd Ed. (2005): ISBN-13: 978-3527405428<br>"Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer, 2nd. Ed. (2006): ISBN-13: 978-3540298557                                                                                                                                                                                                                  |                                                                                           |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                           |                   |                                                          |
| primarily master module                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                           |                   |                                                          |



|                                                                                                                                                                                                          |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                          | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                        |            |                  |                 |
| "Nanoelectronics and Information Technology. Advanced Electronic Materials and Novel Devices", R. Waser (Ed.), Wiley-VCH (2003) "Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer (2004) |            |                  |                 |
|                                                                                                                                                                                                          | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                        |            |                  |                 |
| "Nanoelectronics and Information Technology. Advanced Electronic Materials and Novel Devices", R. Waser (Ed.), Wiley-VCH (2003) "Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer (2004) |            |                  |                 |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Laser Metrology and Material Processing                                                   |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2413580                                                                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                           | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the summer term                                                                   | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                                                                         | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3 / 5,0                                                                                   | Module owner      | Prof. Dr. Tobias Voß                                     |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                                                                       |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 42                                                                                        | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                           |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | oral exam (30 minutes) or written exam (120 minutes), depending on number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Presentation                                                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                           |                   |                                                          |
| Basic laser technology<br>generation of ultrashort laser pulses<br>characterization of laser beams and laser pulses<br>spectroscopy with sub-nanosecond time resolution<br>basics of nonlinear optics<br>light-matter interaction<br>laser-based material processing of semiconductors<br>modern spectroscopy methods in semiconductor technology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                           |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                           |                   |                                                          |
| Students will be familiar with the functionality of modern laser systems used in the field of semiconductor technology and can explain their mode of operation based on theoretical models. They can describe the interaction of laser light with matter theoretically. They analyze optical emission spectra (luminescence, plasma, Raman scattering, time-resolved signals) and can draw conclusions about material and interaction processes. They know the basic processes of laser material processing, especially with modern ultrashort pulse lasers. They can describe nonlinear optical processes theoretically and understand their significance for laser-based methods in semiconductor technology. They record optical spectra from laser-based processes under guidance and independently prepare a scientific evaluation and interpretation, which they present in a short presentation. |                                                                                           |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                           |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                           |                   |                                                          |

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|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 1,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                 |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Statistics, Design of Experiments, Optimization |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2415480                                         | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | only in the summer term                         | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1                                               | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 3 / 5,0                                         | Module owner      | Prof. Dr. Wolfgang Kowalsky                              |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 150                                             |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 54                                              | Self studying (h) | 96                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                 |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Homework                                        |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                 |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                 |                   |                                                          |
| Descriptive and comparative statistics, significance tests, outlier tests, application of important probability distributions (normal distribution, Student's t-distribution, F distribution). Fundamentals of design of experiments and analysis, statistical analysis of obtained factors and models. Introduction to the matrix version of least squares. System optimization with respect to simple and multiple targets. For all modules (I # III): use of free (for academic purposes) state-of-the-art statistical software R and associated integrated programming environment RStudio.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                 |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                 |                   |                                                          |
| Overarching target is to familiarize participants with statistical principles of data analysis, comparison of and inference from experimental data (part I - Statistics), the optimal design of experiments (part II - Design of Experiments), and system optimization (part III - Optimization). Participants will learn to use the state-of-the-art statistical software R and apply the content of the lecture to optimize multi-parameter problems typically encountered in an industrial setting. After attending the course participants will be able to analyze experimental data according to established statistical procedures (test for outliers, confidence intervals for a single response and differences between observations of pairs of responses, evaluation and planning of sample sizes). Part II # Design of Experiments # enables the participants to plan experiments for maximal efficiency and analyze the reliability of the parameters extracted from the data (determination and understanding of the relevance of process variances, confidence intervals and significance of extracted process parameters). Participants furthermore will be skilled in using least-squares methods applied to data analysis and model building. During part III # Optimization # participants will learn to optimize multidimensional systems which include interaction between the controlling factors and multiple, possibly conflicting targets. |                                                 |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                 |                   |                                                          |
| Note: even former editions of the following monographs are well suited for preparation, studies besides, and after the lecture:<br>Box, Hunter, Hunter, Statistics for Experimenters: Design, Innovation, and Discovery (Wiley Series in Probability and Statistics)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                 |                   |                                                          |

Myers, Montgomery, Response Surface Methodology: Process and Product Optimization Using Designed Experiments  
(Wiley Series in Probability and Statistics)  
Montgomery, Design and Analysis of Experiments (Wiley)  
As introduction to R the following free source is recommended as introduction:  
<https://cran.r-project.org/doc/manuals/r-release/R-intro.pdf>



| Related courses                                 |     |                       |          |
|-------------------------------------------------|-----|-----------------------|----------|
| Rules for the choice of courses                 |     |                       |          |
|                                                 |     |                       |          |
| Compulsory attendance                           |     |                       |          |
|                                                 |     |                       |          |
| Name of the course                              | SWS | Eventtype             | Language |
| Statistics, Design of Experiments, Optimization | 2,0 | Lecture               | english  |
| Statistics, Design of Experiments, Optimization | 1,0 | Exercise, small group | english  |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Electromagnetic Compatibility               |                   |                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2419120                                     | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                             | Language          | german                                                        |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                           | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3 / 5,0                                     | Module owner      | Prof. Dr. Thomas Kleine-Ostmann<br>Dr. Harald Spieker         |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                         |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 42                                          | Self studying (h) | 108                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written exam (60 min) or oral exam (30 min) |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                               |
| <ul style="list-style-type: none"><li>• Terms and definitions of EMC</li><li>• Sources of interference and disturbance variables, immunity of susceptible devices #</li><li>• Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference #</li><li>• Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection #</li><li>• Legal basis, product liability, standardization #</li><li>• EMC test engineering #</li><li>• Electromagnetic compatibility of biological systems</li></ul> |                                             |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                               |
| The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able assess the EMC product safety by failure mechanisms.    |                                             |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                               |
| <ul style="list-style-type: none"><li>- Lecture notes</li><li>- Joachim Franz, EMV – Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X</li><li>- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1</li><li>- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9</li></ul>                                                                                                                                                                                                                                 |                                             |                   |                                                               |



| <b>Related courses</b>                                                              |            |                  |                 |
|-------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>                                              |            |                  |                 |
| Either this module or "Electromagnetic Compatibility with Seminar" can be selected. |            |                  |                 |
| <b>Compulsory attendance</b>                                                        |            |                  |                 |
|                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Electromagnetic Compatibility                                                       | 2,0        | Lecture          | german          |
| Electromagnetic Compatibility                                                       | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Electromagnetic Compatibility with Seminar                        |                   |                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2419130                                                           | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                   | Language          | english german                                                |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | only in the winter term                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1                                                                 | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 5 / 6,0                                                           | Module owner      | Prof. Dr. Thomas Kleine-Ostmann                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 180                                                               |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 70                                                                | Self studying (h) | 110                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                   |                                                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Written exam (60 min) or oral exam, presentation of seminar topic |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                   |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                   |                   |                                                               |
| <ul style="list-style-type: none"><li>- Terms and definitions of EMC</li><li>- Sources of interference and disturbance variables, immunity of susceptible devices</li><li>- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference</li><li>- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection</li><li>- Legal basis, product liability, standardization</li><li>- EMC test engineering</li><li>- Electromagnetic compatibility of biological systems</li><li>- Current EMC issues presented in seminar talks</li></ul>                                                                    |                                                                   |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                   |                                                               |
| The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able to assess the EMC product safety by failure mechanisms. The students are able to investigate current EMC issues autonomously, structure and present them to an audience. |                                                                   |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                   |                   |                                                               |
| <ul style="list-style-type: none"><li>- continuously updated script handout</li><li>- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X</li><li>- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1</li><li>- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9</li></ul>                                                                                                                                                                                                                                                                                                                            |                                                                   |                   |                                                               |



|                                                                                                                                                                                                                            |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                     |            |                  |                 |
| You can either choose Electromagnetic Compatibility with Seminar <b>or</b> Electromagnetic Compatibility (without seminar). The seminar can also be attended in the summer semester after having attended the EMC lecture. |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Electromagnetic Compatibility                                                                                                                                                                                              | 2,0        | Lecture          | german          |
| Teacher training college EMC                                                                                                                                                                                               | 2,0        | Seminar          | english         |
| Electromagnetic Compatibility                                                                                                                                                                                              | 1,0        | Exercise         | german          |



| Title                                                                                      | Numerical Methods                                                                                           |                   |                                                             |
|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------------------------------------|
| Number                                                                                     | 2423590                                                                                                     | Module version    |                                                             |
| Shorttext                                                                                  |                                                                                                             | Language          | german                                                      |
| Frequency of offer                                                                         | only in the summer term                                                                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik    |
| Module duration                                                                            | 1                                                                                                           | Institution       | elenia Institut für Hochspannungstechnik und Energiesysteme |
| Hours per Week / ECTS                                                                      | 4 / 5,0                                                                                                     | Module owner      | Prof. Dr. Michael Kurrat                                    |
| Workload (h)                                                                               | 150                                                                                                         |                   |                                                             |
| Class attendance (h)                                                                       | 56                                                                                                          | Self studying (h) | 94                                                          |
| Compulsory requirements                                                                    |                                                                                                             |                   |                                                             |
| Expected performance/<br>Type of examination                                               | written exam (120 min) or oral examination (30 min), documentation of computer programs as independent work |                   |                                                             |
| Course achievement                                                                         |                                                                                                             |                   |                                                             |
| Contents                                                                                   |                                                                                                             |                   |                                                             |
|                                                                                            |                                                                                                             |                   |                                                             |
| Objective qualification                                                                    |                                                                                                             |                   |                                                             |
|                                                                                            |                                                                                                             |                   |                                                             |
| Literature                                                                                 |                                                                                                             |                   |                                                             |
| Numerik symmetrischer Matrizen, H.R.Schwarz, Teubner Verlag Matrizen, R. Zurmühl, Springer |                                                                                                             |                   |                                                             |



|                                 |     |            |          |
|---------------------------------|-----|------------|----------|
| Related courses                 |     |            |          |
| Rules for the choice of courses |     |            |          |
|                                 |     |            |          |
| Compulsory attendance           |     |            |          |
|                                 |     |            |          |
| Name of the course              | SWS | Eventtype  | Language |
|                                 | 2,0 | Lecture    | german   |
|                                 | 2,0 | Laboratory | german   |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Fundamentals of Digital Signal Processing            |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2424480                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                  | every term                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                                    | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                               | 3 / 5,0                                              | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                | 42                                                   | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                      |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                        | Written exam (120 minutes) or oral exam (30 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                                          |
| <ul style="list-style-type: none"><li>- Discrete-time signals and systems #</li><li>- Fourier transforms #</li><li>- Z-transforms and applications #</li><li>- Discrete-time IIR filter design #</li><li>- Discrete-time FIR filter design #</li><li>- Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT) #</li><li>- Basics of multi-rate processing and filter banks</li></ul>                                                                     |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                      |                   |                                                          |
| After completing this module, students will have basic knowledge on the tools of digital signal processing in the time and frequency domain and can apply these tools to corresponding problems.                                                                                                                                                                                                                                                                    |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                      |                   |                                                          |
| <ul style="list-style-type: none"><li>- Lecture notes</li><li>- A.V. Oppenheim, R.W. Schafer, J.R. Buck: "Zeitdiskrete Signalverarbeitung" , Pearson Verlag, 2004</li><li>- K.D. Kammeyer, K. Kroschel: "Digitale Signalverarbeitung" , Teubner Verlag, 2002</li><li>- A.V. Oppenheim, R.W. Schafer, J.R. Buck: "Discrete Time Signal Processing" , Prentice-Hall, 2004</li><li>- H.-W. Schüßler: "Digitale Signalverarbeitung 1" , Springer Verlag, 1994</li></ul> |                                                      |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                      |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                      |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>• A. V. Oppenheim, R. W. Schafer, J. R. Buck: Zeitdiskrete Signalverarbeitung, Pearson Studium, 2004</li> <li>• K. D. Kammeyer, K. Kroschel: Digitale Signalverarbeitung, Teubner Verlag, 2002</li> <li>• A. V. Oppenheim, R. W. Schafer, J. R. Buck: Discrete Time Signal Processing, Prentice Hall, 2004</li> <li>• H.-W. Schüßler: Digitale Signalverarbeitung, Springer Verlag, 1994</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| siehe Vorlesung                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                  |                   |                                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|-------------------|--------------------------------------------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Microwave and Wireless Metrology |                   |                                                                                                  |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2424530                          | Module version    |                                                                                                  |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                  | Language          | german                                                                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the winter term          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik                                         |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze<br>Institut für Nachrichtentechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 4 / 5,0                          | Module owner      | Prof. Dr. Thomas Kürner                                                                          |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                              |                   |                                                                                                  |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 56                               | Self studying (h) | 94                                                                                               |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                  |                   |                                                                                                  |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | oral exam (30 min)               |                   |                                                                                                  |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                  |                   |                                                                                                  |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                  |                   |                                                                                                  |
| <ul style="list-style-type: none"><li>- Introduction to metrology</li><li>- Fundamentals of high-frequency technology</li><li>- Measurements in the time domain</li><li>- Spectrum analysis</li><li>- Vector network analysis</li><li>- Antenna measurement technology</li><li>- Channel measurements</li><li>- Protocol measurement technology</li></ul>                                                                                                                                                                                                                  |                                  |                   |                                                                                                  |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                  |                   |                                                                                                  |
| The lecture deals with the basics of modern communication measurement technology. Students will learn about the measurement of signals and transmission characteristics in the time and frequency domain, antenna measurement technology, protocol measurement technology and channel measurement, which are essential for understanding and using state-of-the-art measuring devices, for example in the field of mobile communications. After completing the module, students will be able to use current measurement systems in research and development independently. |                                  |                   |                                                                                                  |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                  |                   |                                                                                                  |
| <ul style="list-style-type: none"><li>- Slides</li><li>- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde &amp; Schwarz, 2004</li><li>- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde &amp; Schwarz, 2007</li><li>- A.Molisch: Wireless Communications, Wiley, 2005</li></ul>                                                                                                                                                                                                                                                                              |                                  |                   |                                                                                                  |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                  |                   |                                                                                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                  |                   |                                                                                                  |



|                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                            | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Foliensammlung</li> <li>- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde &amp; Schwarz, 2004</li> <li>- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde &amp; Schwarz, 2007</li> <li>- A.Molisch: Wireless Communications, Wiley, 2005</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                            | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Foliensammlung</li> <li>- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde &amp; Schwarz, 2004</li> <li>- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde &amp; Schwarz, 2007</li> <li>- A.Molisch: Wireless Communications, Wiley, 2005</li> </ul> |            |                  |                 |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Applied Quantum Computing: Basics and Devices                                              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2413620                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                            | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the winter term                                                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                                                                          | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3 / 5,0                                                                                    | Module owner      | Prof. Dr. Stefanie Kroker                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                                                                                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                                                                                         | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                            |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (120 min) or oral exam (30 min), alternativ: homework with final presentation |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                            |                   |                                                          |
| <ul style="list-style-type: none"><li>- Basics of Quantum Mechanics</li><li>- From Bit to Qubit</li><li>- Quantum Circuits I</li><li>- Quantum Circuits II</li><li>- Entanglement and Teleportation</li><li>- Algorithms of Quantum Computing</li><li>- Quantum Hardware I</li><li>- Quantum Hardware II</li></ul>                                                                                                                                                                                                                                                                                                                                                              |                                                                                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                            |                   |                                                          |
| <ul style="list-style-type: none"><li>- The students can name the prerequisites for the realization of qubits as well as typical platforms and explain their significance.</li><li>- Students will be able to name the strengths and weaknesses of different hardware platforms in common application scenarios and weigh them against each other.</li><li>- The students can name the essential process steps for the realization of different quantum computer platforms and to explain challenges that may arise in the manufacturing process.</li><li>- Students will be able to use an exemplary platform to explain how selected quantum gates can be realized.</li></ul> |                                                                                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                            |                   |                                                          |
| <p>[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019</p> <p>[2] M. A. Nielsen &amp; I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010</p> <p>[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019</p> <p>[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018</p> <p>[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019</p>                                                                                                                                                                                                                                      |                                                                                            |                   |                                                          |



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|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Applied Quantum Computing: Basics and Devices                                                                                                                                                                                                                                                                                                                                                                   | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| [1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019<br>[2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010<br>[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019<br>[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018<br>[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019 |            |                  |                 |
| Applied Quantum Computing: Basics and Devices                                                                                                                                                                                                                                                                                                                                                                   | 1,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                 |                                                      |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                           | Computer Architecture 1                              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                          | 2416010                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                       |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                              | only in the winter term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                 | 1                                                    | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                           | 4 / 6,0                                              | Module owner      | Prof. Dr. Selma Saidi                                    |
| Workload (h)                                                                                                                                                                                                                                                                                    | 180                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                            | 56                                                   | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                       | Written exam (120 minutes) or oral exam (30 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                              |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                        |                                                      |                   |                                                          |
| <ul style="list-style-type: none"><li>• Introduction to computer architecture</li><li>• Principles of computer architecture (control, pipelining, memory hierarchy)</li><li>• Microprocessors (RISC, ISC)</li><li>• Quantitative computer design</li><li>• Design of instruction sets</li></ul> |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| Students have basic knowledge of modern computer architectures and an understanding of the function of modern computers. With the knowledge they have acquired, they are able to configure computer systems on a component basis and evaluate their performance.                                |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                      |                                                      |                   |                                                          |
| D. Patterson, J. L. Hennessy, Computer Organization and Design #– The Hardware/Software Interface, Morgan Kaufmann Publishers, ISBN 978-0-12-370606-5 #<br>W. Stallings, Computer Organization & Architecture, 6. Edition, Prentice Hall, ISBN-13: 978-0-13-035119-7 #<br>Lecture notes         |                                                      |                   |                                                          |

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|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 1,0        | Exercise         | german          |
|                                        | 3,0        | Lecture          | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Gallium Nitride Technology                  |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2413000030                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                     | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| <p>The course builds on 'Lighting Technology I'. While Lighting Technology I focusses on general questions of lighting and lighting technology, this course discusses LED technology and gallium nitride technology in particular:</p> <ul style="list-style-type: none"><li>• Physical principles of LEDs. Band gap engineering in LEDs.</li><li>• Semiconductor materials for optoelectronics</li><li>• Relationship between material properties and LED properties</li><li>• Manufacturing processes</li><li>• Efficiency considerations</li><li>• Front-end and back-end processing</li><li>• Application examples in general lighting, automotive technology, sensor technology</li><li>• Infrared LEDs, visible light, UV LEDs</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| After completing the module, students will have an overview of the current state of LED technology and the development opportunities that solid state lighting will offer in the future. In addition, they will have a basic understanding of the physical processes within LEDs.                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |

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|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Gallium Nitride Technology             | 2,0        | Lecture          | german          |
| Gallium Nitride Technology             | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Nanostructures on Surfaces                   |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1520000010                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | irregular                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                            | Institution       | Institut für Angewandte Physik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                                      | Module owner      | Prof. Dr. Uta Schlickum                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Oral exam (30 min) or written exam (120 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              |                   |                                                          |
| 1. Physics at Surfaces, A. Zangwill, Cambridge University Press, 1988<br>2. Oberflächenphysik des Festkörpers, M. Henzler und W. Göpel, Teubner Studienbücher, 1994<br>3. Oberflächenphysik, Grundlagen und Methoden, T. Fauster, L. Hammer, K. Heinz, und M.A. Schneider, Oldenbourg Verlag München, 2013<br>4. Scanning Probe Microscopy and Spectroscopy, R. Wiesendanger, Cambridge University Press, 1994<br>5. Applied Scanning Probe Methods, B. Bhushan, H. Fuchs, und S. Hosaka, Springer Berlin Heidelberg, 2004 |                                              |                   |                                                          |

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|                                 |     |           |          |
|---------------------------------|-----|-----------|----------|
| Related courses                 |     |           |          |
| Rules for the choice of courses |     |           |          |
|                                 |     |           |          |
| Compulsory attendance           |     |           |          |
|                                 |     |           |          |
| Name of the course              | SWS | Eventtype | Language |

|                                                                                                                                                                                                                                                                                                                                                                                                        |     |                  |        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------------|--------|
| Nanostructures on Surfaces                                                                                                                                                                                                                                                                                                                                                                             | 3,0 | Lecture/Exercise | german |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                      |     |                  |        |
| <ol style="list-style-type: none"><li>1. Physics at Surfaces, A. Zangwill, Cambridge University Press, 1988</li><li>2. Oberflächenphysik des Festkörpers, M. Henzler und W. Göpel, Teubner Studienbücher, 1994</li><li>3. Oberflächenphysik, Grundlagen und Methoden, T. Fauster, L. Hammer, K. Heinz, und M.A. Schneider, Oldenbourg Verlag München, 2013</li><li>4. Aktuelle Publikationen</li></ol> |     |                  |        |

| Title                                        | Materials and Device Analysis               |                   |                                                          |
|----------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                       | 2413000050                                  | Module version    |                                                          |
| Shorttext                                    |                                             | Language          | english                                                  |
| Frequency of offer                           | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                              | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                        | 3 / 5,0                                     | Module owner      | Prof. Dr. Tobias Voß                                     |
| Workload (h)                                 | 150                                         |                   |                                                          |
| Class attendance (h)                         | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                      |                                             |                   |                                                          |
| Expected performance/<br>Type of examination | written exam (30 min) or oral exam (60 min) |                   |                                                          |
| Course achievement                           |                                             |                   |                                                          |

#### Contents

With a focus on optical and electrical characterisation methods, procedures for the investigation of materials and devices from the field of semiconductor technology are presented:

1. optical spectroscopy and microscopy methods
  1. absorption spectroscopy
  2. fluorescence spectroscopy
  3. time-resolved spectroscopy
  4. IR spectroscopy
  5. Raman spectroscopy and microscopy
  6. photon correlation spectroscopy
2. scanning electron microscopy
3. x-ray diffraction
4. atomic force microscopy
5. electrical measurement techniques
  1. IV
  2. CV
  3. hall effect measurements
  4. Electrical measurement methods in the atomic force microscope

The methods are each explained on the basis of application fields with typical material systems, whereby silicon, III-V/II-VI semiconductors, group III nitrides and common substrate materials (SiC, sapphire) are discussed.

#### Objective qualification

Students are familiar with important optical, electrical and other characterisation methods used in the field of semiconductor technology. They will be able to select suitable methods for specific materials and components and explain and evaluate the information that can be obtained in each case. They will be able to describe the fundamental processes in the material in the respective measurement methods using technical terminology and will be able to plot, analyse and discuss individual measurement results provided.

#### Literature



#### Related courses

##### Rules for the choice of courses

##### Compulsory attendance

##### Name of the course

##### SWS

##### Eventtype

##### Language

Materials and Device Analysis

2,0

Lecture

english

Materials and Device Analysis

1,0

Exercise

english

| Title                                                                                                                                                                                                                                                                                             | Sensor Technology                                                                                                                                             |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                            | 2413000040                                                                                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                         |                                                                                                                                                               | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                | only in the summer term                                                                                                                                       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                   | 1                                                                                                                                                             | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                             | 3 / 5,0                                                                                                                                                       | Module owner      |                                                          |
| Workload (h)                                                                                                                                                                                                                                                                                      | 150                                                                                                                                                           |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                              | 42                                                                                                                                                            | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                           |                                                                                                                                                               |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                                          | Attending Materials & Device Analysis; Fundamentals of NanoOptics; Integrated Circuits for Biomedical Applications in addition to the lecture is recommended. |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                      | Written exam (60 min) or oral exam (30 min)                                                                                                                   |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                | Project work (design project), either with written assignment or final presentation/colloquium                                                                |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                          |                                                                                                                                                               |                   |                                                          |
|                                                                                                                                                                                                                                                                                                   |                                                                                                                                                               |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                           |                                                                                                                                                               |                   |                                                          |
|                                                                                                                                                                                                                                                                                                   |                                                                                                                                                               |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                        |                                                                                                                                                               |                   |                                                          |
| Core Texts: <ul style="list-style-type: none"><li>• Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010</li><li>• Horowitz &amp; Hill: The Art of Electronics (2nd ed), CUP, 1989</li></ul>                                                                                           |                                                                                                                                                               |                   |                                                          |
| Supplementary: <ul style="list-style-type: none"><li>• Pallás-Areny &amp; Webster: Analog Signal Processing, Wiley, 1999</li><li>• MIT OCW readings &amp; lecture notes from MAS#836 Sensor Technologies</li><li>• Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)</li></ul> |                                                                                                                                                               |                   |                                                          |





|                                                                                                                                                                                                                                                                                        |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                 |            |                  |                 |
|                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                           |            |                  |                 |
|                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Sensor Technology                                                                                                                                                                                                                                                                      | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                      |            |                  |                 |
| Core Texts:                                                                                                                                                                                                                                                                            |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010</li> <li>• Horowitz &amp; Hill: The Art of Electronics (2nd ed), CUP, 1989</li> </ul>                                                                                         |            |                  |                 |
| Supplementary:                                                                                                                                                                                                                                                                         |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Pallás-Areny &amp; Webster: Analog Signal Processing, Wiley, 1999</li> <li>• MIT OCW readings &amp; lecture notes from MAS#836 Sensor Technologies</li> <li>• Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)</li> </ul> |            |                  |                 |
| Sensor Technology                                                                                                                                                                                                                                                                      | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                      |            |                  |                 |
| Project and sensor type-specific; s. lecture for literature and provided articles.                                                                                                                                                                                                     |            |                  |                 |

**Major Specialisation: Autonomous Intelligent Systems - Compulsory Elective Modules**

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Sensors with Lab                                                                         |                   |                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2411160                                                                                  | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                          | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | only in the summer term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1                                                                                        | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 6 / 8,0                                                                                  | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 240                                                                                      |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 84                                                                                       | Self studying (h) | 156                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | oral exam (30 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                          |                   |                                                                        |
| <b>Contents</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                          |                   |                                                                        |
| <ul style="list-style-type: none"><li>- Characteristics of measuring sensors</li><li>- Temperature measurement</li><li>- Magnetic field measurement</li><li>- Optical sensors</li><li>- Measurement of geometric quantities</li><li>- Measurement of dynamometric quantities</li><li>- Flow measurement</li></ul>                                                                                                                                                                                                                                                                                                                                      |                                                                                          |                   |                                                                        |
| <b>Objective qualification</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                          |                   |                                                                        |
| After completing the module ‘Sensors for non-electrical quantities’, students will have an overview of the use and dimensioning of electrical sensors for non-electrical quantities. The in-depth fundamentals enable the selection, use and error assessment of modern sensors. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary qualifications are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation, dialogue and presentation techniques as well as teamwork in the laboratory or project. |                                                                                          |                   |                                                                        |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                          |                   |                                                                        |
| <ul style="list-style-type: none"><li>- P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag), ISBN 978-3486225921</li><li>- H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart), ISBN 978-3519061250</li><li>- J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag), ISBN 978-3540622314</li><li>- J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig), ISBN 978-3446219779</li></ul>                                                                                                                                                                                                       |                                                                                          |                   |                                                                        |



|                                                                                                                                                                                                                                                                                       |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                             | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                       | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |
|                                                                                                                                                                                                                                                                                       | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |
|                                                                                                                                                                                                                                                                                       | 3,0        | Laboratory       | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                      |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                            | Automated Road Vehicles: from Assistance to Autonomy |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                           | 2412620                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                        |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                                    | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                                              | Module owner      | Prof. Dr. Markus Maurer                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                     | 150                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                             | 56                                                   | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                          |                                                      |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                        | Written exam (60 min) or oral exam (30 min)          |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                               |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| <div>-probabilistic knowledge representation for driver assistance and vehicle guidance systems</div> <div>- radar-based and visual machine perception</div> <div>- machine situation detection and behavioural decision-making</div> <div>- human-machine-interaction</div> <div>- design and test of driver assistance and vehicle guidance systems</div>                                                      |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                          |                                                      |                   |                                                          |
| After completing this module, students will have basic knowledge of driver assistance systems and automated vehicles. They are familiar with the current state of the art in driver assistance systems and automated driving functions and know about the function-determining factors. The students are able to independently plan customer-value driver assistance systems and systems for vehicle automation. |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                       |                                                      |                   |                                                          |
| <div>- Handbook of Driver Assistance Systems; Basic Information, Components and Systems for Active Safety and Comfort; Editors: Winner, H., Hakuli, S., Lotz, F., Singer, C. (eds.); 1. Edition 2016 Springer; available free of charge for students via Springer-Link</div>                                                                                                                                     |                                                      |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                           |                                                      |                   |                                                          |
| The course “Automotive Systems Engineering” provides helpful background knowledge for this course; however, it is not a mandatory prerequisite for participation.                                                                                                                                                                                                                                                |                                                      |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| Only one of the three modules ET-IFR-42, ET-IFR-58, ET-IFR-62 can be chosen.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Hermann Winner (Hrsg.), Stephan Hakuli (Hrsg.), Gabriele Wolf (Hrsg.): Handbuch Fahrerassistenzsysteme Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort, Springer, 3. Auflage 2015, ISBN: 978-3658057336</li> <li>- R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111</li> <li>- M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964</li> <li>- S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Hermann Winner (Hrsg.), Stephan Hakuli (Hrsg.), Gabriele Wolf (Hrsg.): Handbuch Fahrerassistenzsysteme Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort, Springer, 3. Auflage 2015, ISBN: 978-3658057336</li> <li>- R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111</li> <li>- M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964</li> <li>- S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                      | Advanced Computer Architecture |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                     | 2416520                        | Module version    |                                                          |
| Shorttext                                                                                                                                                                                  |                                | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                         | only in the winter term        | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                            | 1                              | Institution       | Institut für Computer Engineering                        |
| Hours per Week / ECTS                                                                                                                                                                      | 3 / 5,0                        | Module owner      | Prof. Dr. Selma Saidi                                    |
| Workload (h)                                                                                                                                                                               | 150                            |                   |                                                          |
| Class attendance (h)                                                                                                                                                                       | 42                             | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                    |                                |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                               | oral exam (20 min)             |                   |                                                          |
| Course achievement                                                                                                                                                                         |                                |                   |                                                          |
| Contents                                                                                                                                                                                   |                                |                   |                                                          |
|                                                                                                                                                                                            |                                |                   |                                                          |
| Objective qualification                                                                                                                                                                    |                                |                   |                                                          |
|                                                                                                                                                                                            |                                |                   |                                                          |
| Literature                                                                                                                                                                                 |                                |                   |                                                          |
| - J. L. Hennessy & David A. Patterson, "Computer Architecture - A Quantitative Approach (4th rev. Edition)", Academic Press, ISBN 978-0123704900<br>- additional materials during lectures |                                |                   |                                                          |



|                                 |     |           |          |
|---------------------------------|-----|-----------|----------|
| Related courses                 |     |           |          |
| Rules for the choice of courses |     |           |          |
|                                 |     |           |          |
| Compulsory attendance           |     |           |          |
|                                 |     |           |          |
| Name of the course              | SWS | Eventtype | Language |
|                                 | 2,0 | Lecture   | german   |
|                                 | 1,0 | Exercise  | german   |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Pattern Recognition                       |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2424690                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                           | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | every term                                | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1                                         | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 4 / 5,0                                   | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 150                                       |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 56                                        | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                           |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Oral exam 30 min. or written exam 90 min. |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                           |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                           |                   |                                                          |
| <div>- Bayesian decision rule</div> <div>- Quality metrics in pattern recognition</div> <div>- Supervised learning with parametric distributions</div> <div>- Supervised learning with non-parametric distributions, classification</div> <div>- Linear discriminant functions, single-layer perceptron</div> <div>- Support vector machines (SVMs)</div> <div>- Multi-layer perceptron, neural networks (NNs)</div> <div>- Deep learning</div> <div>- Unsupervised learning, clustering methods</div> <div>Note: For pattern recognition using hidden Markov models (HMMs), a separate more in-depth module, Spoken Language Processing (ET-NT-68), is offered in the summer semester.</div> |                                           |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                           |                   |                                                          |
| Upon completion of this module, students gain fundamental knowledge about methods and algorithms for classification of data. They are capable to select the appropriate means for real-world problems, to design a solution and to evaluate it.                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                           |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                           |                   |                                                          |
| <div>- R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001</div> <div>- C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                           |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                           |                   |                                                          |
| Basic knowledge of statistics, such as acquired in the module "Probability Theory and Statistics", facilitates the understanding of the lecture.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |                   |                                                          |



|                                                                                                                                                                                                                                            |            |                  |                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                            | 2,0        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001</li> <li>- C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006</li> </ul>                             |            |                  |                 |
|                                                                                                                                                                                                                                            | 2,0        | Seminar          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Vorlesungsfolien</li> <li>- R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001</li> <li>- C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006</li> </ul> |            |                  |                 |



**Major Specialisation: Autonomous Intelligent Systems - Elective Modules**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                          |                   |                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Sensors with Lab                                                                         |                   |                                                                        |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 2411160                                                                                  | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                          | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | only in the summer term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1                                                                                        | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 6 / 8,0                                                                                  | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 240                                                                                      |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 84                                                                                       | Self studying (h) | 156                                                                    |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                                        |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | oral exam (30 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                          |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                          |                   |                                                                        |
| <ul style="list-style-type: none"><li>- Characteristics of measuring sensors</li><li>- Temperature measurement</li><li>- Magnetic field measurement</li><li>- Optical sensors</li><li>- Measurement of geometric quantities</li><li>- Measurement of dynamometric quantities</li><li>- Flow measurement</li></ul>                                                                                                                                                                                                                                                                                                                                      |                                                                                          |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                                        |
| After completing the module ‘Sensors for non-electrical quantities’, students will have an overview of the use and dimensioning of electrical sensors for non-electrical quantities. The in-depth fundamentals enable the selection, use and error assessment of modern sensors. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary qualifications are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation, dialogue and presentation techniques as well as teamwork in the laboratory or project. |                                                                                          |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                          |                   |                                                                        |
| <ul style="list-style-type: none"><li>- P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag), ISBN 978-3486225921</li><li>- H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart), ISBN 978-3519061250</li><li>- J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag), ISBN 978-3540622314</li><li>- J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig), ISBN 978-3446219779</li></ul>                                                                                                                                                                                                       |                                                                                          |                   |                                                                        |



|                                                                                                                                                                                                                                                                                       |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                             | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                       | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |
|                                                                                                                                                                                                                                                                                       | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |
|                                                                                                                                                                                                                                                                                       | 3,0        | Laboratory       | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |            |                  |                 |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Precision Measuring Techniques                                                           |                   |                                                                        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2411210                                                                                  | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                          | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                                                                        | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                                                                                  | Module owner      | Prof. Dr. Meinhard Schilling                                           |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                                                                                      |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                                                                                       | Self studying (h) | 94                                                                     |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                          |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | oral exam (30 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                          |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                          |                   |                                                                        |
| <ul style="list-style-type: none"><li>- Measuring at physical limits</li><li>- Fundamentals of quantum effects and construction of precision devices</li><li>- Electrical and magnetic properties of Josephson elements,</li><li>- SQUIDs (Superconducting Quantum Interference Devices), SETs (Single Electron Tunnelling),</li><li>- Cryogenic current comparators and quantised resistors</li><li>- Accurate DC and AC voltage sources</li><li>- Measurement of small electrical voltages, currents, charges and magnetic fields</li><li>- Application examples in medicine, research and industry.</li></ul> |                                                                                          |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                          |                   |                                                                        |
| After completing the 'Precision Metrology' module, students will have an overview of the fundamentals of precision metrology and primary standards at PTB and metrology in Germany. Through a field trip to the PTB, students learn about the structure of primary standards and the dissemination of SI units. The students are able to apply this knowledge in the analysis and design of measurement and sensor systems.                                                                                                                                                                                      |                                                                                          |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                          |                   |                                                                        |
| V. Kose, F. Melchert "Quantenmaße in der elektrischen Messtechnik", VCH 1991, ISBN 3-527-28380-3<br>J. Hoffmann "Handbuch der Messtechnik", Hanser Verlag 2004, ISBN 3-446-21123-3<br>F. Kohlrausch "Praktische Physik" Teubner Verlag 1996, ISBN 3-519-23000-3<br>K. Kopitzki "Einführung in die Festkörperphysik" Teubner-Verlag 2007, ISBN 3-835-10144-7<br>W. Buckel und R. Kleiner "Supraleitung", Wiley-VCH Verlag, Weinheim, 2004, ISBN 3-527-40348-5<br>Further literature will be announced during the lecture                                                                                          |                                                                                          |                   |                                                                        |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                          |                   |                                                                        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                          |                   |                                                                        |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
| <b>Literature</b>                      |            |                  |                 |
| Wird in der Vorlesung bekannt gegeben  |            |                  |                 |
|                                        | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Quality Assurance and Optimization                                                          |                   |                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2411220                                                                                     | Module version    |                                                                        |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                             | Language          | german                                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | only in the winter term                                                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1                                                                                           | Institution       | Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 4 / 5,0                                                                                     | Module owner      | Prof. Dr. Oleksandr Dobrovolskiy                                       |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 150                                                                                         |                   |                                                                        |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 56                                                                                          | Self studying (h) | 94                                                                     |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                             |                   |                                                                        |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Written exam (45 min); written exam (120 min) only in case of large numbers of participants |                   |                                                                        |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                             |                   |                                                                        |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                             |                   |                                                                        |
| Introduction to the measurement process<br>Systematic and random measurement uncertainties/errors Noise and noise analysis<br>Determination of measurement uncertainty according to GUM<br>Fundamentals of applied statistics: distribution functions, estimation theory, hypothesis tests, error propagation<br>Equalisation calculation, regression analysis<br>Statistical design of experiments<br>Quality management                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                             |                   |                                                                        |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                             |                   |                                                                        |
| After completing the module, students will have an overview of the fundamentals of quality management and process optimisation. Thanks to the practical knowledge acquired, students will be able to solve simple optimisation tasks using statistical design of experiments.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                             |                   |                                                                        |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                             |                   |                                                                        |
| - E. Schrüfer: Elektrische Messtechnik (Hanser Verlag 2007), ISBN 978-3446409040<br>- W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall 1991), ISBN 978-0023805523<br>- O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag 1978), ISBN 978-3411001194<br>- N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons 1977), ISBN 978-0471017561 und 978-0471017578<br>- Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig 1974, im Bibliotheksbestand<br>- B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH, 2004), ISBN 978-3833010392<br>- G. Linß: Qualitätsmanagement für Ingenieure (Hanser Fachbuchverlag Leipzig 2005), ISBN 978-3446228214 |                                                                                             |                   |                                                                        |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <ul style="list-style-type: none"> <li>• E. Schröder: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall)</li> <li>• O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag)</li> <li>• N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley &amp; Sons)</li> <li>• Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig</li> <li>• B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH)</li> <li>• G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <ul style="list-style-type: none"> <li>• E. Schröder: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall)</li> <li>• O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag)</li> <li>• N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley &amp; Sons)</li> <li>• Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig</li> <li>• B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH)</li> <li>• G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Digital Signal Processing with Microcontrollers                                          |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2411260                                                                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                          | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the summer term                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                                                        | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                                                                  | Module owner      | Prof. Dr. Meinhard Schilling                             |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                                                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                                                                                       | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                          |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | oral exam (30 min); written exam (120 min) only in case of large numbers of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                          |                   |                                                          |
| Statistical treatment of measurement data,<br>Interpolation of measurement data,<br>Signal analysis: discrete (DFT) and fast (FFT) Fourier transformation<br>z-transform: digital filters, correlation, simulation of a closed control loop,<br>Controller and controlled system as IIR and FIR filters.<br>Assembly language of microprocessors<br>Implementation of digital signal processing algorithms in assembler and C                                                                                                                                                                                                                                                             |                                                                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                          |                   |                                                          |
| After completing the module 'Digital Measurement Data Processing with Microcomputers', students will have an overview of the functionality and programming of microcontrollers for measurement data processing. The acquired practical knowledge enables the programming of embedded systems for metrological applications. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary skills are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation, dialogue and presentation techniques as well as teamwork in the laboratory or project. |                                                                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                          |                   |                                                          |
| A multimedia CD-ROM with lecture notes and exercises is offered for the lecture<br>- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984, ISBN 978-3519001416<br>- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985, ISBN 978-3486298451<br>- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979, ISBN 978-3486245288<br>- Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983, ISBN 978-3486244328                                      |                                                                                          |                   |                                                          |

↑

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984</li> <li>• Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985</li> <li>• Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979</li> <li>• Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984</li> <li>• Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985</li> <li>• Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979</li> <li>• Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983</li> </ul> |            |                  |                 |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                    |                   |                           |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|-------------------|---------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Automation Engineering                                             |                   |                           |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2412280                                                            | Module version    |                           |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                    | Language          | german                    |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the winter term                                            | Teaching unit     | Fakultät für Maschinenbau |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                                                                  | Institution       |                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 4 / 5,0                                                            | Module owner      | Prof. Dr. Jürgen Pannek   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                                                                |                   |                           |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                                                                 | Self studying (h) | 108                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                    |                   |                           |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Control Theory or Fundamentals of Control Engineering              |                   |                           |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1 examination element: written exam (90 min) or oral exam (30 min) |                   |                           |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                    |                   |                           |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                    |                   |                           |
| Lecture/Tutorial: <ul style="list-style-type: none"><li>• Aim of automation engineering</li><li>• Basics, tasks and methods of automation</li><li>• Coupling and hierarchies of systems</li><li>• Information and information management</li><li>• Control, modularization and standardization in automation</li><li>• Digitalization for industrial internet, industrial cloud and CPS</li><li>• Basics of knowledge management, industrial big data and decision support</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                    |                   |                           |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                    |                   |                           |
| After having completed the module automation engineering, students are able to reproduce and explain extensive basic and methodological knowledge of automation systems as well as their components (process computer, actuators, sensors, HMI). First of all, this contains that the students can explain the classification, the control and the coupling of technical processes exemplarily. They are also able to analyze information in technical processes and in signals, including signal detection and signal conversion, based on simple case examples. In addition, the students can describe basic computer structures in automation technology as well as the basics of the representation and processing of information in process computer systems in principle. Therefore, they can explain the mechanisms of process control for real-time capability and the task concept of operating systems exemplarily. They are also able to fundamentally categorize organizational, distribution and communication structures of automation systems based on simple case examples. In addition, students can reproduce basic knowledge concerning the means of description Petri Nets and are able to apply that means independently in order to model processes. |                                                                    |                   |                           |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                    |                   |                           |
| <ul style="list-style-type: none"><li>• Lunze, J.: Automatisierungstechnik. 5. Auflage. DeGruyter (2020)</li><li>• Plenk,V.: Grundlagen der Automatisierungstechnik kompakt, Springer (2019)</li><li>• Lai, C.: Intelligent Manufacturing, Springer (2022)</li><li>• LangmannN, C.; Turi, D.: Robotic process automation – Digitalisierung und Automatisierung von Prozessen. Springer (2020)</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                    |                   |                           |

- Stjepandic, J.; Sommer, M.; Denkena, B.: DigiTwin: An approach for production process optimization in a built environment, Springer (2022)



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
| exercise and project are optional      |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Automation Engineering                 | 2,0        | Lecture          | english         |
| Automation Engineering                 | 2,0        | Exercise         | english         |
|                                        | 1,0        | Project          | german          |
| <b>Literature</b>                      |            |                  |                 |
| keine                                  |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                        | Robust Control Design                       |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                       | 2412440                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                    |                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                           | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                              | 1                                           | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                        | 4 / 5,0                                     | Module owner      | Marcus Grobe                                             |
| Workload (h)                                                                                                                                                                                                                                                                                                 | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                         | 56                                          | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                 | oral exam (30 min) or written exam (60 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
| Optimal state control, Kalman filter, LQG, norms of signals and systems, internal stability, parameter uncertainty, coprime decomposition, Youla parameterization, minimization of the 2-/inf-norm, H2-/Hinf-optimal control, $\mu$ -synthesis, robust stability, CAD exercises with MATLAB                  |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| Students are able to analyze and design controllers in the field of norm-optimal, robust control engineering. After completing the module, students will have an overview of modern methods for designing controllers for systems with pronounced uncertainties and are able to investigate their stability. |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| - K. Müller: Entwurf robuster Regelungen, Teubner-Verlag, ISBN: 978-3519061731<br>- K. Zhou, J. C. Doyle: Robust and Optimal Control, ISBN: 978-0134565675<br>- K. Zhou, J. C. Doyle: Essentials of Robust Control, Prentice-Hall, ISBN: 978-0135258330                                                      |                                             |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| Requirement: Lecture "Fundamentals of Control Engineering"                                                                                                                                                                                                                                                   |                                             |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
| German                                 |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|                       |     |          |        |
|-----------------------|-----|----------|--------|
| Robust Control Design | 2,0 | Lecture  | german |
| Robust Control Design | 2,0 | Exercise | german |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Vehicle Electronics                         |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2412480                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1                                           | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3 / 5,0                                     | Module owner      | Prof. Dr. Markus Maurer                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>- Product development process of vehicles</li><li>- Automotive electrics and electronics including requirements and standards</li><li>- Hardware architecture of electronic vehicle systems</li><li>- Electrical energy in the vehicle</li><li>- Wiring system, design criteria, wiring system architecture and development process</li><li>- Electronic systems in the powertrain</li><li>- Alternative energy sources and drive concepts</li><li>- Chassis control</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Upon completion of this module, students will have an overview of the complexity of the vehicle development process and about environment, requirements and boundary conditions for electronic systems in motor vehicles. In particular, they have acquired an understanding of the architectures of ECUs and sensors and basic sensor principles using the example of selected system functions in the field of drivetrain and chassis development.                                                                 |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>- Folien zur Vorlesung - Bosch: Autoelektrik Autoelektronik, Vieweg Verlag</li><li>- M. Krüger: Grundlagen der Kraftfahrzeugelektronik, Hanser Verlag</li><li>- J. Schäuffele, T. Zurawka: Automotive Software Engineering, Vieweg Verlag</li><li>- Bosch: Sicherheits- und Komfortsysteme, Vieweg Verlag</li></ul>                                                                                                                                                            |                                             |                   |                                                          |



|                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                 |            |                  |                 |
| German                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                           |            |                  |                 |
|                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                        | 1,0        | Exercise         | german          |
|                                                                                                                                                                                                                                                                                                        | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Folien zur Vorlesung</li> <li>- Bosch: Autoelektrik Autoelektronik, Vieweg Verlag</li> <li>- M. Krüger: Grundlagen der Kraftfahrzeugelektronik, Hanser Verlag</li> <li>- J. Schäuffele, T. Zurawka: Automotive Software Engineering, Vieweg Verlag</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                    | Postgraduate Seminar Vehicle Electronics |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                   | 2412510                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                |                                          | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                       | every term                               | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                          | 1                                        | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                    | 2 / 5,0                                  | Module owner      | Prof. Dr. Markus Maurer                                  |
| Workload (h)                                                                                                                                                                                                                                                                             | 150                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                     | 28                                       | Self studying (h) | 122                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                  |                                          |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                | Written elaboration or oral exam         |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                       |                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                 |                                          |                   |                                                          |
| Changing current research topics from the field of electronic vehicle systems                                                                                                                                                                                                            |                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                  |                                          |                   |                                                          |
| After completion of this module, the students will have advanced skills in writing scientific papers. Within the scope of the advanced seminar, changing current research topics from the field of electronic vehicle systems will be elaborated, deepened and scientifically processed. |                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                               |                                          |                   |                                                          |
|                                                                                                                                                                                                                                                                                          |                                          |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                   |                                          |                   |                                                          |
| The module can only be taken once. Participants will be admitted to the course by the person responsible for the module in order to ensure that the qualification objectives of the module can be achieved.                                                                              |                                          |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 0,0        | Project          | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Design of Digital Control Systems with MATLAB |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2412560                                       | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                               | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                            | only in the winter term                       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1                                             | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 4 / 5,0                                       | Module owner      | Prof. Dr. Markus Maurer                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 150                                           |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 56                                            | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                               |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                  | Written exam (60 min) or oral exam (30 min)   |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                               |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                               |                   |                                                          |
| Dynamic state estimation:<br>Probability theory and distribution functions, system descriptions, filtering and smoothing, Kalman and particle filters<br><br>Nonlinear optimization methods:<br>Necessary and sufficient optimality conditions, one-dimensional minimization, minimization without constraints, minimization with constraints                                                                                                                                 |                                               |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                               |                   |                                                          |
| After completing this module, students will have basic knowledge of numerical optimization methods and associated standard software libraries. They are also familiar with methods and the current state of the art for object tracking in the field of machine perception of automated vehicles. Students will be able to independently solve optimization problems for electronic vehicle systems and implement algorithms for object tracking with radar or lidar sensors. |                                               |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                               |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                               |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                   |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Advanced Topics in Automotive Systems Engineering |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2412590                                           | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                   | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the winter term                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                                                 | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 3 / 5,0                                           | Module owner      | Prof. Dr. Markus Maurer                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                                               |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 42                                                | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                   |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Presentation (§ 9 (7) APO)                        |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                   |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                   |                   |                                                          |
| Automotive industry is changing rapidly these days. Both electric drives and autonomous driving change the requirements on vehicles dramatically. These changes include innovative vehicle systems, vehicle concepts and many aspects of systems engineering. In this class, selected topics will be presented and discussed by both scientists and students. These topics include electric vehicles, autonomous driving, safety and security aspects, system architecture, development processes and other related fields. |                                                   |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                   |                   |                                                          |
| The students will study selected scientific topics in automotive systems engineering on an advanced level. They will be trained to present a scientific topic of their choice to a scientific audience. Adjacent to their presentation they have to defend their major theses in an extended discussion.                                                                                                                                                                                                                    |                                                   |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                   |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                   |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |
|                                        | 2,0 | Seminar   | english  |
|                                        | 1,0 | Training  | english  |

|                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                      |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                            | Automated Road Vehicles: from Assistance to Autonomy |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                           | 2412620                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                        |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                                    | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                                              | Module owner      | Prof. Dr. Markus Maurer                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                     | 150                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                             | 56                                                   | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                          |                                                      |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                        | Written exam (60 min) or oral exam (30 min)          |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                               |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| <div>-probabilistic knowledge representation for driver assistance and vehicle guidance systems</div> <div>- radar-based and visual machine perception</div> <div>- machine situation detection and behavioural decision-making</div> <div>- human-machine-interaction</div> <div>- design and test of driver assistance and vehicle guidance systems</div>                                                      |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                          |                                                      |                   |                                                          |
| After completing this module, students will have basic knowledge of driver assistance systems and automated vehicles. They are familiar with the current state of the art in driver assistance systems and automated driving functions and know about the function-determining factors. The students are able to independently plan customer-value driver assistance systems and systems for vehicle automation. |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                       |                                                      |                   |                                                          |
| <div>- Handbook of Driver Assistance Systems; Basic Information, Components and Systems for Active Safety and Comfort; Editors: Winner, H., Hakuli, S., Lotz, F., Singer, C. (eds.); 1. Edition 2016 Springer; available free of charge for students via Springer-Link</div>                                                                                                                                     |                                                      |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                           |                                                      |                   |                                                          |
| The course “Automotive Systems Engineering” provides helpful background knowledge for this course; however, it is not a mandatory prerequisite for participation.                                                                                                                                                                                                                                                |                                                      |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| Only one of the three modules ET-IFR-42, ET-IFR-58, ET-IFR-62 can be chosen.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Hermann Winner (Hrsg.), Stephan Hakuli (Hrsg.), Gabriele Wolf (Hrsg.): Handbuch Fahrerassistenzsysteme Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort, Springer, 3. Auflage 2015, ISBN: 978-3658057336</li> <li>- R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111</li> <li>- M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964</li> <li>- S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Hermann Winner (Hrsg.), Stephan Hakuli (Hrsg.), Gabriele Wolf (Hrsg.): Handbuch Fahrerassistenzsysteme Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort, Springer, 3. Auflage 2015, ISBN: 978-3658057336</li> <li>- R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111</li> <li>- M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964</li> <li>- S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics</li> </ul> |            |                  |                 |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | High-Voltage Safety in the Motor Vehicle            |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2412650                                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                     | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the winter term                             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                                   | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3 / 5,0                                             | Module owner      | Prof. Dr. Markus Maurer                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                                                  | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                     |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | oral exam (30 minutes) or written exam (60 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Lab course                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                     |                   |                                                          |
| <p>The contents result primarily from the qualification measures QM2b+3a of the German Legal Accident Insurance (DGUV) Information 200-005 for work on vehicles with high-voltage systems. Electrotechnical work in a voltage-free state on non-HV intrinsically safe systems level 2 according to DGUV Information 200-005" and working under voltage and near touchable live parts Level 3 according to DGUV Information 200-005".</p>                                                                                                                                                                                                                                        |                                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                     |                   |                                                          |
| <p>After completing this module, the students have basic knowledge on HV safety resulting from the qualification measures QM2b+3a of DGUV Information 200-005 for work on vehicles with high-voltage systems. They achieved in particular, an understanding of the electrical hazards associated with the use of HV systems in vehicles. The students will understand and be able to apply appropriate processes guaranteeing safety and health in electrotechnical work under high voltage.</p> <p>The qualification is documented with the successful participation in the practical exercises as well as a proof of the acquired skills and knowledge by an examination.</p> |                                                     |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                     |                   |                                                          |
| <ul style="list-style-type: none"><li>• Folien zum Seminarinhalt</li><li>• Arbeitsblätter</li><li>• Gesetzliche Unterlagen wie:</li><li>• DGUV Information 200-005 (bisherige Bezeichnung: BGI/GUV-I 8686)</li><li>• ECE R 100</li><li>• DGUV Regel 103-011 (bisherige Bezeichnung: BGR A3)</li></ul>                                                                                                                                                                                                                                                                                                                                                                           |                                                     |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                     |                   |                                                          |
| <p>Compulsory attendance at the seminar:</p> <p>Participation in the seminar is required and recorded by attendance list and signature. It will be carried out short tests on the individual contents in the event.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                     |                   |                                                          |

The attendance as well as the tests in the seminar are mandatory so that the lecturer is able to assess the individual level of knowledge and training of the participants as well as their personal suitability before the students will perform experiments of their own.

Limitation of the number of participants:

The number of participants is limited to 20 people so that the required practical part is sufficiently can be mediated.

Additional note:

The practical exercises take place at the institute's training stands. Training contents include measurements of the output voltages on a frequency converter and the replacement of battery cells. These works will be performed under high voltage. If they are not carried out in accordance with the regulations and with the necessary knowledge, they are life threatening. It is therefore important to reduce the risk for students. The lecturer must therefore obtain an overview of the level of knowledge and training of the participants as well as their personal suitability in advance. This goal is achieved through compulsory attendance and tests in the seminar.



|                                                                                                                                                                                                           |            |                  |                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                    |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                           |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                           |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                 | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                           | 2,0        | Seminar          | german          |
| <b>Literature</b>                                                                                                                                                                                         |            |                  |                 |
| Folien zum Seminarinhalt<br>Arbeitsblätter<br>Gesetzliche Unterlagen wie: DGUV Information 200-005 (bisherige Bezeichnung: BGI/GUV-I 8686), ECE R 100, DGUV Regel 103-011 (bisherige Bezeichnung: BGR A3) |            |                  |                 |
|                                                                                                                                                                                                           | 1,0        | Internship       | german          |
| <b>Literature</b>                                                                                                                                                                                         |            |                  |                 |
| Folien zum Seminarinhalt<br>Arbeitsblätter<br>Gesetzliche Unterlagen wie: DGUV Information 200-005 (bisherige Bezeichnung: BGI/GUV-I 8686), ECE R 100, DGUV Regel 103-011 (bisherige Bezeichnung: BGR A3) |            |                  |                 |

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|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Nonlinear Control Systems                                                             |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2412670                                                                               | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                       | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | only in the summer term                                                               | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                                                                     | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 4 / 5,0                                                                               | Module owner      | Marcus Grobe                                             |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 150                                                                                   |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 56                                                                                    | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                       |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Written exam 60 minutes or oral exam 30 minutes (depending on number of participants) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                       |                   |                                                          |
| Fundamentals and application of nonlinear control theory, Lyapunov stability theory, exact linearization, Sliding mode control, method of the description function for non-linear systems (harmonic linearization)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                       |                   |                                                          |
| After completing the module, students will be able to describe non-linear systems in the form of differential equations.<br>With the help of Lyapunov's stability theory, students are able to describe the rest positions of non-linear systems and assess their stability.<br>The learned method of exact linearization enables students to apply known methods of linear controller design to non-linear systems with affine input. Exact linearization compensates for the non-linearities present in the system using a nonlinearities present in the system by means of a feedback law and thus allows the design of a linear controller.<br>Using the method of sliding-mode control, students are enabled to design switching controllers based on state-dependent switching between different control laws and to evaluate them with regard to the limit cycles that occur.<br>limit cycles.<br>In addition, using the harmonic balance method, students acquire the ability to analyze oscillations and limit cycles in non-linear systems and to make statements as to whether these oscillations will actually occur. |                                                                                       |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                       |                   |                                                          |
| Jürgen Adamy: Nichtlineare Regelungen. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009<br>Jean-Jaques E. Slotine; Weiping Li: Applied nonlinear control, Englewood Cliffs, NJ: Prentice Hall, 1991                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                       |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                       |                   |                                                          |
| Requirement: Lecture "Fundamentals of Control Engineering" and "Advanced Control Engineering"                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                       |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                  |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Control of Electrical Devices                                                    |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2412680                                                                          | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                  | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the winter term                                                          | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                                                | Institution       | Institut für Elektrische Maschinen, Antriebe und Bahnen  |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 4 / 5,0                                                                          | Module owner      | Prof. Dr. Markus Henke                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                                                              |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 56                                                                               | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                  |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | oral exam (30 min) or written exam (60 min), depending on number of participants |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                  |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                  |                   |                                                          |
| motion equation and non-stationary movement, heating processes, dynamic behaviour of DC and AC motor drives, servo drives with inverters, control of inverter drives with DC and AC motors, sensor-less field-oriented control                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                  |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                  |                   |                                                          |
| Students understand the models of DC and AC motor drives and the mathematical concept of space vectors and can utilise them in simulations. They know the control structures for the motor types DC motor, asynchronous machine and synchronous machine with and without speed sensor. They can design and analyse their own control structures and tune the control parameters. They understand sensors commonly used in drive systems like compensated current sensor, resolver, incremental angular sensor and the corresponding evaluation functions. They can use the principle of space vector modulation and similar modulation methods to design their own hardware and software. |                                                                                  |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                  |                   |                                                          |
| - W. Leonhard: Regelung elektrischer Antriebe, Springer-Verlag, ISBN: 978-3540671794<br>- W. Leonhard: Control of electrical Drives, Springer-Verlag, ISBN: 978-3540418207                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                  |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                  |                   |                                                          |
| Requirements: Lecture „Fundamentals of control technologies“                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                  |                   |                                                          |





|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 2,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Semiconductor Sensors   |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2413340                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                         | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the winter term | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                       | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                 | Module owner      | Prof. Dr. Erwin Peiner                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                      | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                         |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | oral exam (30 min)      |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |
| <div>- Elementary sensors: periodic excitation, mass, damping coefficient, spring constant, accelerometer, noise, vibration sensor, yaw rate sensor, bending stiffness/force sensor/transfer standard, Film Stress/Thermal Sensor, Diaphragm/Pressure/Flow Sensor, Overload Resistance/Impact Sensor</div> <div>- Transducers: pressure sensor (capacitive/optical transducer), acceleration sensor (capacitive transducer), Acceleration Sensor (piezoelectric transducer), vibration sensor/acceleration sensor (optical transducer), force sensor (piezoresistive transducer), vibration sensor (piezoresistive transducer, piezoresistive sensor with fiber optic readout), yaw rate sensor (drive and detection), acceleration sensor (tunnel-effect transducer), comparison and rating</div> <div>- Surface micromachining: diffusion, oxidation, layer deposition, lithography, wet/dry etching, sticking, integration with CMOS</div> <div>- Volume micromachining: implantation/diffusion, metallization (evaporation/cathode sputtering), isotropic/anisotropic etching, electrochemical etching</div> <div>- Epi-micromachining: Epi-poly, conformal deposition, SIMPLE, SCREAM, black silicon, SOI, electrochemical etching, porous silicon, hetero-micromachining, comparison</div> <div>- Condition monitoring: machine tool, sensor/technology, roller bearings, kinematic frequencies, bogie bearing, signal analysis (envelope/resonant), calender roll, EMC/ fiber-optic readout, cavitation</div> <div>- Engine management: combustion process, combustion engine efficiency, cylinder pressure indexing, average indicated pressure pmi, cylinder filling, heating process, engine control with adaptive pre-control, sensors</div> <div>- Micro/nano metrology</div> |                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                         |                   |                                                          |
| <div>After completing the module semiconductor sensors, the students will have</div> <div>- a basic understanding of the most important methods for modelling, fabrication and characterization of micro-/nano-mechanical semiconductor sensors</div> <div>- the ability to select suitable manufacturing processes for the realization of micro- and nano-structured semiconductor sensors</div> <div>- in-depth knowledge and practical experience in designing sensors</div> <div>- knowledge for assessing and evaluating possible uses of micro-/nano-mechanical sensors</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                         |                   |                                                          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <p>A. Heuberger (Hrsg): Mikromechanik (Springer, Berlin, 1989) ISBN: 3-540-18721-9</p> <p>M.-H. Bao: Handbook of Sensors and Actuators 8 - Micro Mechanical Transducers (Elsevier, Amsterdam, 2000) ISBN 0-444-50558-X S. Büttgenbach: Mikromechanik (Teubner, Stuttgart, 1994) ISBN: 3-519-13071-8</p> <p>M. Elwenspoek, R. Wiegerink: Mechanical Microsensors (Springer, Berlin, 2001) ISBN: 3-540-67582-5</p> <p>E. Peiner: Silizium-Sensorik für die Maschinenüberwachung (Shaker, Aachen 2000) ISBN: 3-8265-7401-X</p> <p>Skript und Übungsunterlagen werden verteilt.</p> |



|                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                     | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <p>A. Heuberger (Hrsg): Mikromechanik (Springer, Berlin, 1989) M.-H. Bao: Handbook of Sensors and Actuators 8 - Micro Mechanical Transducers (Elsevier, Amsterdam, 2000) S. Büttgenbach: Mikromechanik (Teubner, Stuttgart, 1994) M. Elwenspoek, R. Wiegerink: Mechanical Microsensors (Springer, Berlin, 2001)</p> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                     | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| Übungsunterlagen und Vorlesungsskript werden verteilt.                                                                                                                                                                                                                                                              |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Design of Electrical Machines                |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2414200                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | only in the winter term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1                                            | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 4 / 5,0                                      | Module owner      | Prof. Dr. Markus Henke                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                          | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>• Force and torque buildup in electrical machines</li><li>• Winding design of rotating field machines</li><li>• Winding factor calculation</li><li>• Fundamentals of thermal modelling of electrical machines</li><li>• Cooling mechanisms</li><li>• Finite element methods for electromagnetic machine design</li><li>• Analytical design of electrical machines</li><li>• Motor topologies for automotive and aviation applications</li></ul> |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |                   |                                                          |
| After completing the module, the students have in-depth knowledge of the function of rotating electric machines and the physical intervention options for speed control. The deepened fundamentals enable the design of simple drives taking into account possible fault conditions as well as the entry into the design of electrical machines.                                                                                                                                      |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| Binder, Elektrische Maschinen und Antriebe: Grundlagen, Betriebsverhalten, Springer<br>G. Müller, B. Ponick: Theorie elektrischer Maschinen, VCH<br>H.O. Seinsch, Ausgleichsvorgänge bei elektrischen Antrieben, Teubner Verlag, Stuttgart                                                                                                                                                                                                                                            |                                              |                   |                                                          |

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|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                          | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                        |            |                  |                 |
| G. Müller, Theorie elektrischer Maschinen, VCH Verlagsgesellschaft mbH, ISBN: 3-527-28392-7 H.O. Seinsch, Ausgleichsvorgänge bei elektrischen Antrieben, Teubner Verlag, Stuttgart, 1991 |            |                  |                 |
|                                                                                                                                                                                          | 2,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Drives for Electric Road Vehicles            |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2414220                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the winter term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                                            | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 4 / 5,0                                      | Module owner      | Prof. Dr. Markus Henke                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              |                   |                                                          |
| The module teaches a system-oriented approach to the design of electric drives in road vehicles by considering the vehicle as a mechatronic system. Starting from the basics of drive design (driving resistances, power transmission), common drive topologies of road vehicles are dealt with. Special features of the motors used with regard to their function and their properties as inverter-fed drives are dealt with. The knowledge gained here on the design and dimensioning of traction drives is then applied to road vehicles (electric and hybrid vehicles). |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |
| After completing the module, the students know the essential structures of conventional and new types of vehicle drives and the electrical machines and converters used in these vehicles. They are also able to carry out a simple design.                                                                                                                                                                                                                                                                                                                                 |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| Babiel, Elektrische Antriebe in der Fahrzeugtechnik, Vieweg<br>Reif, Noreikat, Bergeest, Kraftfahrzeug-Hybridantriebe, Springer                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |
|                                        | 1,0 | Lecture   | german   |

|  |     |          |        |
|--|-----|----------|--------|
|  | 1,0 | Lecture  | german |
|  | 2,0 | Exercise | german |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                         |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Antennas and Electromagnetic Radiation                  |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2415360                                                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                         | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term                                 | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                                       | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4 / 6,0                                                 | Module owner      | Prof. Dr. Jörg Schöbel                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 180                                                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 56                                                      | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                         |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Written exam (90 min) or oral exam (30 min) or homework |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                         |                   |                                                          |
| <div>- electromagnetic theory founded on Maxwell's equations and respective calculation techniques (wave equation, solution of the inhomogeneous wave equation, source integrals, Huygens' principle, image theory, Hertzian dipole)</div> <div>- basic antenna structures, characteristic parameters of antennas</div> <div>- array antennas and beamforming, synthesis of antenna patterns</div> <div>- aperture antennas, Fourier transformation, horn and slot antennas, parabolic antennas, Physical Optics</div> <div>- wave propagation, diffraction limit of free-space propagation, static models, radar cross section</div> <div>- antenna and RCS characterization methods</div> <div>- modern state of the art and current research topics</div> |                                                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                         |                   |                                                          |
| After completing the module, students will have an in-depth understanding of electromagnetic theory for radiation fields as well as a basic understanding of wave propagation and related phenomena (e.g. Radar cross section). They have become familiar with different types of antenna elements as well as array antennas and have a clear and well-founded theoretical understanding of their electromagnetic properties and their parameters. The students have gained first experiences in the use of modern 3D-EM simulation tools and modern RF measurement techniques and are able to acquire further in-depth knowledge in the application of these tools on their own.                                                                            |                                                         |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                         |                   |                                                          |
| Unger, Hochfrequenztechnik in Funk und Radar, Teubner-Verlag, ISBN 3519300184<br>Unger, Elektromagnetische Theorie für die Hochfrequenztechnik, Hüthig-Verlag, ISBN 377851573X<br>Pozar, Microwave Engineering, Wiley, ASIN B001QA4I9C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                         |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                         |                   |                                                          |
| Prerequisites: Mathematics, Electromagnetic Fields, Fundamentals of Information Technology, Guided Electromagnetic Waves                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                         |                   |                                                          |





| <b>Related courses</b>                 |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Antennas and Electromagnetic Radiation | 1,0        | Exercise         | german          |
|                                        | 3,0        | Lecture          | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Radar Systems and Signal Processing                         |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2415450                                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the summer term                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                                           | Institution       | Institut für Hochfrequenztechnik                         |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                                     | Module owner      | Prof. Dr. Jörg Schöbel                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 64                                                          | Self studying (h) | 86                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | oral exam (30 min) or written exam (60 min) or project work |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                             |                   |                                                          |
| <p>The module provides an overview of radar systems and their signal processing. Different radar concepts (pulse, FMCW, ...), their associated hardware, and the most important key terms and concepts of signal processing are considered. Automotive radar systems are emphasized.</p> <p>After completion of the module the students will have in-depth knowledge of radar system concepts in connection with the associated circuit concepts and signal processing and will be able to evaluate and conceptually design radar systems on this basis. Students have knowledge of the most important algorithms used in radar signal processing and have gained experience in the function and interaction of radar hardware and software. This extends from signal generation and signal acquisition to signal evaluation (range and velocity determination) and angle determination with array antennas. This enables the students to work on detailed questions in radar system development and to acquire the associated special knowledge independently.</p> |                                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                             |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                             |                   |                                                          |
| <p>Requirements: it is recommended to have completed the module “RF and Microwave Systems and Circuits” expected knowledge:</p> <ul style="list-style-type: none"><li>- introduction to RF circuits (S parameters, concept of matching)</li><li>- transmission line theory</li><li>- antenna and radio transmission basics (dipole antenna, antenna parameters, Friis transmission equation, link budget)</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                             |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 2,0        | Exercise         | german          |

| Title                                                                                                                                                                                      | Advanced Computer Architecture |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                     | 2416520                        | Module version    |                                                          |
| Shorttext                                                                                                                                                                                  |                                | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                         | only in the winter term        | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                            | 1                              | Institution       | Institut für Computer Engineering                        |
| Hours per Week / ECTS                                                                                                                                                                      | 3 / 5,0                        | Module owner      | Prof. Dr. Selma Saidi                                    |
| Workload (h)                                                                                                                                                                               | 150                            |                   |                                                          |
| Class attendance (h)                                                                                                                                                                       | 42                             | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                    |                                |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                               | oral exam (20 min)             |                   |                                                          |
| Course achievement                                                                                                                                                                         |                                |                   |                                                          |
| Contents                                                                                                                                                                                   |                                |                   |                                                          |
|                                                                                                                                                                                            |                                |                   |                                                          |
| Objective qualification                                                                                                                                                                    |                                |                   |                                                          |
|                                                                                                                                                                                            |                                |                   |                                                          |
| Literature                                                                                                                                                                                 |                                |                   |                                                          |
| - J. L. Hennessy & David A. Patterson, "Computer Architecture - A Quantitative Approach (4th rev. Edition)", Academic Press, ISBN 978-0123704900<br>- additional materials during lectures |                                |                   |                                                          |



|                                 |     |           |          |
|---------------------------------|-----|-----------|----------|
| Related courses                 |     |           |          |
| Rules for the choice of courses |     |           |          |
|                                 |     |           |          |
| Compulsory attendance           |     |           |          |
|                                 |     |           |          |
| Name of the course              | SWS | Eventtype | Language |
|                                 | 2,0 | Lecture   | german   |
|                                 | 1,0 | Exercise  | german   |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Network Security                            |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2416530                                     | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                             | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                           | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3 / 5,0                                     | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>- Mathematical foundations of cryptology and information security</li><li>- Functions of public and secret key cryptology</li><li>- Authentication and data security protocols</li><li>- Current applications and standards of IP network security</li><li>- Current applications and standards of wireless network security</li><li>- Network commerce and payment systems</li><li>- Selected current advanced network security topics</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                          |
| After completing the module, the students are able to use the acquired basic knowledge of current cryptology to design basic crypto systems and assess their level of security.<br>The students have acquired the ability, by means of the common techniques of protocols and standards of network security, to analyse fundamental features of a security design in current network environments, and apply basic design methods of network security.                                  |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>• W. Adi, lecture notes and exercises</li><li>• William Stallings, Network Security Essentials: Applications and Standards, 3rd Edition, Prentice Hall, © 2007, ISBN-10: 0-13-238033-1</li><li>• Charlie Kaufman, Radia Perlman, Mike Speciner, Network Security: Private Communication in a Public World (2nd edition), Prentice Hall, 2002, ISBN-10: 0130460192</li></ul>                                                                       |                                             |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                          | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <ul style="list-style-type: none"> <li>W. Adi, Vorlesungsfolien und Übungen. William Stallings, Network Security Essentials: Applications and Standards, 3rd Edition, Prentice Hall, © 2007, ISBN-10: 0-13-238033-1</li> <li>Charlie Kaufman, Radia Perlman, Mike Speciner, Network Security: Private Communication in a Public World (2nd edition), Prentice Hall, 2002, ISBN-10: 0130460192</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                          | 1,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                      |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Computer Architecture Basics and Lab                 |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2416620                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | only in the summer term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1                                                    | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 8 / 10,0                                             | Module owner      | Prof. Dr. Rolf Ernst                                     |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 300                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 112                                                  | Self studying (h) | 188                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (120 minutes) or oral exam (30 Minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Lab course                                           |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                      |                   |                                                          |
| Introduction to computer architecture<br>Principles of computer architecture (control, pipelining, memory hierarchy)<br>Microprocessors (RISC, ISC)<br>Quantitative computer design and design of instruction sets<br>Practical experiments in the following areas<br>Metrological investigation of line effects and synchronisation methods<br>Assembler and automaton implementation on microcontrollers<br>Circuit design using hardware design languages<br>Circuit synthesis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                                          |
| The students have basic knowledge of modern computer architectures and an understanding of the function of modern computers. With the knowledge they have acquired, they are able to configure computer systems on a component basis and evaluate their performance.<br>In the Lab course, students will be able to design simple circuits and embedded software and evaluate the result in terms of its logical and temporal behaviour by means of measurements or simulation. They will be able to formulate and implement a hardware design in a design language and gain an overview of the phases of a complex hardware design. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary skills are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation, dialogue and presentation techniques as well as teamwork in the laboratory or project. |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| -# Computer Organization and Design<br>- The Hardware/Software Interface, 3rd edition, David A. Patterson and John L. Hennessy<br>- Lecture / lab notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 1,0        | Exercise         | german          |
|                                        | 4,0        | Internship       | german          |
|                                        | 3,0        | Lecture          | german          |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Embedded Computing Systems with Lab |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2416640                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                     | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the winter term             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2                                   | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 8 / 10,0                            | Module owner      | Prof. Dr. Rolf Ernst                                     |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 300                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 112                                 | Self studying (h) | 188                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                     |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                     |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                     |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                     |                   |                                                          |
| Introduction to computer architecture<br>Principles of computer architecture (control, pipelining, memory hierarchy)<br>Microprocessors (RISC, ISC)<br>Quantitative computer design and design of instruction sets<br>Practical experiments from the following areas<br>Construction of an Application Specific Instruction Set Processor (ASIP)<br>Hardware design with a hardware description language (VHDL)<br>Programming / extension of the software for the ASIP (C)<br>Hardware / software co-design<br>Implementation of applications on an ASIP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                     |                   |                                                          |
| - Students have detailed knowledge of modern computer architectures and an advanced understanding of the function of modern computers. With the knowledge they have acquired, they are able to configure complex computer systems on a component basis and evaluate their performance in detail.<br>In the Embedded Processors internship, students learn about the areas of application and potential uses of Application Specific Instruction Set Processors (ASIPs). They are then able to break down larger tasks into sub-problems and solve them in teamwork. They will have mastered the competent use of complex tools and design processes for hardware and software design. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary skills are taught and practiced. In the context of papers, colloquia and final presentations, these include scientific writing and documentation, dialogue and presentation techniques as well as teamwork in the laboratory or project. |                                     |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                     |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                     |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 3,0        | Lecture          | german          |
|                                        | 1,0        | Exercise         | german          |
|                                        | 4,0        | Internship       | german          |
| <b>Literature</b>                      |            |                  |                 |
| Skript                                 |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Network-Security                             |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2416770                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                            | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 3 / 5,0                                      | Module owner      | Prof. Dr. Admela Jukan                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 42                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |
| The lecture gives a broad introduction to network security, including foundations of cryptography, message integrity, authentication, privacy and anonymity, application layer security, secure network protocols, security in the physical layer, as well as broader aspects security aspects related to reliability and safety. It also discusses relevant topics in various application domains, such as (i) security in next generation mobile networks, (ii) satellite network security; (iii) security in the compute continuum of IoT, edge and cloud computing; (v) security functions within the network management; (vi) physical layer security in optical and wireless networks. |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |
| On finishing this module the students have a survey of the theoretical principles of cryptography. They are able to analyze basic cryptographic systems and are able to design basic electronic security systems.                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Material provided to students in StudIP, including the references noted within                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                              |                   |                                                          |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|                                                                                |     |          |        |
|--------------------------------------------------------------------------------|-----|----------|--------|
|                                                                                | 2,0 | Lecture  | german |
| <b>Literature</b>                                                              |     |          |        |
| Material provided to students in StudIP, including the references noted within |     |          |        |
|                                                                                | 1,0 | Exercise | german |
| <b>Literature</b>                                                              |     |          |        |
| Material provided to students in StudIP, including the references noted within |     |          |        |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Advanced Topics in Real-Time Embedded Operating Systems               |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2416800                                                               | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                       | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | every term                                                            | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                                                     | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3 / 5,0                                                               | Module owner      | Prof. Dr. Rolf Ernst                                     |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                                                                   |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                                                                    | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                       |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | oral exam 30 min.                                                     |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | presentation or development and documentation of a computer programme |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                       |                   |                                                          |
| <div>- Requirements, design constraints and tradeoffs for real-time embedded systems</div> <div>- Relevant aspects of operating systems (Multi-Threading, Multi-Core, Synchronization, Mixed-Criticality)</div> <div>- Relevant aspects of real-time systems (Execution model, scheduling, resource sharing)</div> <div>- optional: industrial perspective on embedded real-time systems</div> <div>- overview on existing operating systems for embedded real-time applications</div> <div>- Schedulability Analysis</div> <div>- Student talks on topic related papers</div>                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                       |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                       |                   |                                                          |
| <p>The students will develop an understanding of the fundamental concepts of real-time embedded operating systems (RTOS) and their most relevant requirements (e.g. temporal predictability and reliability). The students will acquire in-depth knowledge about different design choices associated to RTOS that are currently relevant in the academic and the industrial domain. Moreover, the students will be able to critically reason about the trade-offs associated to the aforementioned design choices, and will be able to identify the conditions under which they could be used for the development of safety-critical applications. Through individual and group work of practical nature the students will learn how to develop and implement certain aspects of RTOS. Moreover the students will acquire a set of skills essential for scientific research and publishing, such as the abilities to present and critically review scientific publications.</p> |                                                                       |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                       |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                       |                   |                                                          |

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|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Electromagnetic Compatibility               |                   |                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2419120                                     | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                             | Language          | german                                                        |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1                                           | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 3 / 5,0                                     | Module owner      | Prof. Dr. Thomas Kleine-Ostmann<br>Dr. Harald Spieker         |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 150                                         |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 42                                          | Self studying (h) | 108                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written exam (60 min) or oral exam (30 min) |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                               |
| <ul style="list-style-type: none"><li>• Terms and definitions of EMC</li><li>• Sources of interference and disturbance variables, immunity of susceptible devices #</li><li>• Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference #</li><li>• Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection #</li><li>• Legal basis, product liability, standardization #</li><li>• EMC test engineering #</li><li>• Electromagnetic compatibility of biological systems</li></ul> |                                             |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                               |
| The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able assess the EMC product safety by failure mechanisms.    |                                             |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                               |
| <ul style="list-style-type: none"><li>- Lecture notes</li><li>- Joachim Franz, EMV – Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X</li><li>- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1</li><li>- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9</li></ul>                                                                                                                                                                                                                                 |                                             |                   |                                                               |



| <b>Related courses</b>                                                              |            |                  |                 |
|-------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>                                              |            |                  |                 |
| Either this module or "Electromagnetic Compatibility with Seminar" can be selected. |            |                  |                 |
| <b>Compulsory attendance</b>                                                        |            |                  |                 |
|                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Electromagnetic Compatibility                                                       | 2,0        | Lecture          | german          |
| Electromagnetic Compatibility                                                       | 1,0        | Exercise         | german          |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Electromagnetic Compatibility with Seminar                        |                   |                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-------------------|---------------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2419130                                                           | Module version    |                                                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                   | Language          | english german                                                |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | only in the winter term                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1                                                                 | Institution       | Institut für Elektromagnetische Verträglichkeit und Bordnetze |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 5 / 6,0                                                           | Module owner      | Prof. Dr. Thomas Kleine-Ostmann                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 180                                                               |                   |                                                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 70                                                                | Self studying (h) | 110                                                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                   |                                                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Written exam (60 min) or oral exam, presentation of seminar topic |                   |                                                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                   |                   |                                                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                   |                   |                                                               |
| <ul style="list-style-type: none"><li>- Terms and definitions of EMC</li><li>- Sources of interference and disturbance variables, immunity of susceptible devices</li><li>- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference</li><li>- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection</li><li>- Legal basis, product liability, standardization</li><li>- EMC test engineering</li><li>- Electromagnetic compatibility of biological systems</li><li>- Current EMC issues presented in seminar talks</li></ul>                                                                    |                                                                   |                   |                                                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                   |                   |                                                               |
| The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able to assess the EMC product safety by failure mechanisms. The students are able to investigate current EMC issues autonomously, structure and present them to an audience. |                                                                   |                   |                                                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                   |                   |                                                               |
| <ul style="list-style-type: none"><li>- continuously updated script handout</li><li>- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X</li><li>- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1</li><li>- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9</li></ul>                                                                                                                                                                                                                                                                                                                            |                                                                   |                   |                                                               |



|                                                                                                                                                                                                                            |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                     |            |                  |                 |
| You can either choose Electromagnetic Compatibility with Seminar <b>or</b> Electromagnetic Compatibility (without seminar). The seminar can also be attended in the summer semester after having attended the EMC lecture. |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Electromagnetic Compatibility                                                                                                                                                                                              | 2,0        | Lecture          | german          |
| Teacher training college EMC                                                                                                                                                                                               | 2,0        | Seminar          | english         |
| Electromagnetic Compatibility                                                                                                                                                                                              | 1,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                     |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Analog Integrated Circuits with Lab |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2420140                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                     | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the summer term             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                   | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 6 / 8,0                             | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 240                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 84                                  | Self studying (h) | 156                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                     |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Oral exam (30 min)                  |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                     |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                     |                   |                                                          |
| <p>All modern mobile communications applications (e.g., GSM, WLAN, GPS, Bluetooth, DECT, etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are increasingly being integrated into low-cost CMOS technology, resulting in significant differences from the classic design of high-frequency circuits based on discrete components. The lecture provides an introduction to the design of analog, integrated CMOS mobile communications receiver circuits.</p> <p>The lecture is divided into the following chapters:</p> <ul style="list-style-type: none"><li>• High-frequency amplifier circuits</li><li>• Simulation of electronic noise</li><li>• Low-noise input amplifiers in CMOS</li><li>• Mixer circuits</li><li>• HPhase-locked loops (PLLs)</li><li>• Voltage-controlled oscillators</li></ul>                                                                                                                                                                                                                        |                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                     |                   |                                                          |
| <p>After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).</p> <p>They will acquire fundamental knowledge in the use of the Spectre-RF design tool, which is widely used in industry for the design of analog integrated circuits.</p> <p>In accordance with the didactic concept of the course and the structure of the individual components, interdisciplinary skills are taught and practiced. These include scientific writing and documentation, conversation</p> |                                     |                   |                                                          |

and presentation techniques, and teamwork in the laboratory or on projects, which are covered in assignments, colloquia, and final presentations.

**Literature**

# Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press

**Remark**

For the Master's degree programs in Electrical Engineering, Industrial Engineering Electrical Engineering, and Information Systems Engineering



**Related courses**

**Rules for the choice of courses**

Requirements for this module: circuit technology (*Schaltungstechnik*, ST)

**Compulsory attendance**

| Name of the course                | SWS | Eventtype  | Language |
|-----------------------------------|-----|------------|----------|
| Analog Integrated Circuits (2013) | 1,0 | Exercise   | english  |
| Analog Integrated Circuits (2013) | 1,0 | Internship | english  |
| Analog Integrated Circuits (2013) | 2,0 | Lecture    | english  |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Analog Integrated Circuits |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2420150                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                          | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                    | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                         | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam 30 min           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                   |                                                          |
| <p>All modern mobile radio applications (e.g. GSM, WLAN, GPS, Bluetooth, Dect. etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are increasingly being integrated in low-cost CMOS technology, which results in significant differences to the classic design of high-frequency circuits based on discrete components. The lecture gives an introduction to the design of analog, integrated CMOS mobile radio receiver circuits.</p> <p>The lecture is divided into the following chapters:</p> <ul style="list-style-type: none"><li>- High frequency amplifier circuits</li><li>- Simulation of electronic noise</li><li>- Low-noise input amplifiers in CMOS</li><li>- Mixer circuits</li><li>- Phase-locked loops (PLLs)</li><li>- Voltage-controlled oscillators</li></ul> |                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| <p>After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                   |                                                          |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits" Cambridge University Press                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |

↑

| <b>Related courses</b>                            |            |                  |                 |
|---------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>            |            |                  |                 |
| Prerequisite for this module: Circuit Design (ST) |            |                  |                 |
| <b>Compulsory attendance</b>                      |            |                  |                 |
|                                                   |            |                  |                 |
| <b>Name of the course</b>                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Analog Integrated Circuits (2013)                 | 1,0        | Exercise         | english         |
| Analog Integrated Circuits (2013)                 | 2,0        | Lecture          | english         |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Electrical Railways     |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2423430                 | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                         | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the summer term | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                       | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                 | Module owner      | Prof. Dr. Bernd Engel                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                      | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                         |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | oral exam (30 min)      |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                         |                   |                                                          |
| <p>The module provides an overview of electric railway systems and their stationary and mobile electrical components. The closely related electric road bus systems (trolleybus, battery bus with inductive charging) are also considered.</p> <p>are also considered.</p> <p>0 . Repetitorium: Fundamentals of electrical engineering and electrical power engineering for electric railways</p> <p>1 Introduction: Classification of railway vehicles and electric road bus systems</p> <p>2. national and international stationary traction current systems, DC and AC</p> <p>3. electric drives</p> <ul style="list-style-type: none"><li>- Historical development of drive topologies</li><li>- Inverter systems</li><li>- Drive control</li><li>- Traction motors and mechanical drive configurations</li><li>- Internal combustion vehicles/power transmission types</li></ul> <p>4. auxiliary systems</p> <ul style="list-style-type: none"><li>- Heating, air conditioning and ventilation</li><li>- Batteries, local grid feeds</li><li>- Auxiliary converter topologies</li></ul> <p>5. signalling and security systems</p> <ul style="list-style-type: none"><li>- Overview of the most important systems used in Europe</li><li>- On-board equipment</li></ul> <p>6. control technology on railway vehicles</p> <ul style="list-style-type: none"><li>- Tasks: Control and diagnostics</li><li>- Train and vehicle buses and their components</li></ul> <p>7. passenger information and multimedia</p> <p>8 Vehicles operated</p> <p>TRAXX, EuroSprinter, ICE 3, LIREX, ET 423, regional urban railway Regio CITADIS for Kassel, LINT</p> <p>9. future developments</p> <p>Fuel cell, electronic transformer, gearless direct drive, hybrid vehicles, contactless energy transmission</p> <p>energy transmission</p> <p>10. electric road bus systems (trolleybus, battery bus with inductive/conductive charging)</p> |                         |                   |                                                          |

A free one-day excursion to Alstom Transport Deutschland in Salzgitter and to another destination is also offered.

### Objective qualification

After completing the module, students will be able to understand electrical railway systems with regard to the functioning of their components and to evaluate their properties.

### Literature

Andreas Steimel: Elektrische Triebfahrzeuge und ihre Energieversorgung: Grundlagen und Praxis. Oldenbourg Industrieverlag  
Zarko Filipovic: Elektrische Bahnen: Grundlagen, Triebfahrzeuge, Stromversorgung. Springer Verlag  
Biesenack, Hartmut u. a.: Energieversorgung elektrischer Bahnen. Teubner Verlag



### Related courses

#### Rules for the choice of courses

#### Compulsory attendance

#### Name of the course

#### SWS

#### Eventtype

#### Language

1,0

Exercise

german

### Literature

Andreas Steimel: Elektrische Triebfahrzeuge und ihre Energieversorgung: Grundlagen und Praxis. Oldenbourg Industrieverlag  
Zarko Filipovic: Elektrische Bahnen: Grundlagen, Triebfahrzeuge, Stromversorgung. Springer Verlag  
Biesenack, Hartmut u.a.: Energieversorgung elektrischer Bahnen. Teubner Verlag

3,0

Lecture

german

### Literature

Andreas Steimel: Elektrische Triebfahrzeuge und ihre Energieversorgung: Grundlagen und Praxis. Oldenbourg Industrieverlag  
Zarko Filipovic: Elektrische Bahnen: Grundlagen, Triebfahrzeuge, Stromversorgung. Springer Verlag  
Biesenack, Hartmut u.a.: Energieversorgung elektrischer Bahnen. Teubner Verlag



|                                                                                                                                                                                                                                                                                                                    |                                                                                   |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                              | Speech Communication                                                              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                             | 2424500                                                                           | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                          |                                                                                   | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                 | only in the winter term                                                           | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                    | 1                                                                                 | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                              | 4 / 5,0                                                                           | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                       | 150                                                                               |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                               | 56                                                                                | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                            |                                                                                   |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                       | oral exam (30 min) or written exam (90 min) (according to number of participants) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                 | Colloquium or laboratory protocol as proof of performance                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                           |                                                                                   |                   |                                                          |
| <ul style="list-style-type: none"><li>• Speech production</li><li>• Speech perception</li><li>• Linear prediction and speech modelling</li><li>• Speech coding</li><li>• Noise reduction</li><li>• Acoustic echo compensation</li></ul>                                                                            |                                                                                   |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                            |                                                                                   |                   |                                                          |
| After completing this module, students are capable of digital speech signal processing and can apply acquired knowledge of speech production and speech perception as well as algorithms and methods of speech enhancement, speech coding, speech transmission in mobile communication systems, and Voice over IP. |                                                                                   |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                         |                                                                                   |                   |                                                          |
| <ul style="list-style-type: none"><li>- Copies of lecture slides</li><li>- P.Vary u. R.Martin: Digital Speech Transmission, Wiley 2006</li></ul>                                                                                                                                                                   |                                                                                   |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                             |                                                                                   |                   |                                                          |
| This module of the Master's programme is also suited for Bachelor students.<br>Basic knowledge of digital signal processing, e.g., acquired through the module Fundamentals of Digital Signal Processing, facilitate comprehension of this lecture. Basic knowledge of probability calculus is also helpful.       |                                                                                   |                   |                                                          |



|                                                                                         |            |                  |                 |
|-----------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                  |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                  |            |                  |                 |
|                                                                                         |            |                  |                 |
| <b>Compulsory attendance</b>                                                            |            |                  |                 |
|                                                                                         |            |                  |                 |
| <b>Name of the course</b>                                                               | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                         | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                       |            |                  |                 |
| Kopien der Vorlesungsfolien P.Vary u. R.Martin: Digital Speech Transmission, Wiley 2006 |            |                  |                 |
|                                                                                         | 2,0        | Laboratory       | german          |
| <b>Literature</b>                                                                       |            |                  |                 |
| siehe Vorlesung                                                                         |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                     |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Advanced Seminar "Machine Learning" |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2424600                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                     | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                   | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2 / 5,0                             | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 28                                  | Self studying (h) | 122                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                     |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Written paper                       |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                     |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                     |                   |                                                          |
| Changing current research topics in the field of machine learning.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                     |                   |                                                          |
| After completing the module, students will possess advanced skills in writing a scientific paper. In the course of the advanced seminar, current research topics from the area of machine learning are discussed, deepened, and scientifically prepared. The participants will read scientific publications, present them and discuss them jointly. The structure of a scientific conference publication will be covered as well as strategies for the writing of the standard sections of a paper.<br>This course has a discursive character, therefore regular attendance of the participants is required. |                                     |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                     |                   |                                                          |
| Literature will be handed out in the seminar                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                     |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                     |                   |                                                          |
| Basic knowledge of the topics "pattern recognition"/"machine learning" is expected, especially in the field of neural networks and support vector machines.                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                     |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

|                                       |     |         |        |
|---------------------------------------|-----|---------|--------|
|                                       | 2,0 | Lecture | german |
| <b>Literature</b>                     |     |         |        |
| Literatur wird im Seminar ausgegeben. |     |         |        |
|                                       | 0,0 | Project | german |
| <b>Literature</b>                     |     |         |        |
| Literatur wird im Seminar ausgegeben. |     |         |        |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                       |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Spoken Language Processing                                                            |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2424680                                                                               | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                       | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the winter term                                                               | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                                                                     | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 4 / 5,0                                                                               | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                                                                   |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 56                                                                                    | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                       |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Oral exam 30 minutes or written exam 90 minutes (depending on number of participants) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                       |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                       |                   |                                                          |
| <div>- Basics of speech production and perception</div> <div>- Feature extraction</div> <div>- Hidden Markov models</div> <div>- Acoustic models and language models</div> <div>- Automatic speech recognition</div> <div>- Spoken language systems</div>                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                       |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                       |                   |                                                          |
| After successful completion of the module, students will be able to classify time series (e.g., speech signals) using hidden Markov modeling. The students acquire all the necessary knowledge to suitably select, design, and evaluate methods and algorithms for automatic speech recognition to solve problems in practice.                                                                                                                                                                                                                                                                                                            |                                                                                       |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                       |                   |                                                          |
| <div>- Lecture slides</div> <div>- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001</div> <div>- B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008</div> <div>- A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004</div> <div>- E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995</div> <div>- G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003</div> <div>- L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993</div> <div>- K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990</div> |                                                                                       |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                       |                   |                                                          |
| This module from the master's program is also suitable for bachelor students. Basic knowledge of digital signal processing, as e.g. acquired in the module #digital signal processing#, facilitates the understanding of this lecture.                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                       |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <ul style="list-style-type: none"> <li>- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001</li> <li>- B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008</li> <li>- A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004</li> <li>- E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995</li> <li>- G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003</li> <li>- L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993</li> <li>- K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2,0        | Seminar          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <ul style="list-style-type: none"> <li>- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001</li> <li>- B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008</li> <li>- A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004</li> <li>- E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995</li> <li>- G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003</li> <li>- L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993</li> <li>- K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990</li> </ul> |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Pattern Recognition                       |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2424690                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                           | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | every term                                | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1                                         | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 4 / 5,0                                   | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 150                                       |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 56                                        | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                           |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Oral exam 30 min. or written exam 90 min. |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                           |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                           |                   |                                                          |
| <div>- Bayesian decision rule</div> <div>- Quality metrics in pattern recognition</div> <div>- Supervised learning with parametric distributions</div> <div>- Supervised learning with non-parametric distributions, classification</div> <div>- Linear discriminant functions, single-layer perceptron</div> <div>- Support vector machines (SVMs)</div> <div>- Multi-layer perceptron, neural networks (NNs)</div> <div>- Deep learning</div> <div>- Unsupervised learning, clustering methods</div> <div>Note: For pattern recognition using hidden Markov models (HMMs), a separate more in-depth module, Spoken Language Processing (ET-NT-68), is offered in the summer semester.</div> |                                           |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                           |                   |                                                          |
| Upon completion of this module, students gain fundamental knowledge about methods and algorithms for classification of data. They are capable to select the appropriate means for real-world problems, to design a solution and to evaluate it.                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                           |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                           |                   |                                                          |
| <div>- R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001</div> <div>- C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                           |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                           |                   |                                                          |
| Basic knowledge of statistics, such as acquired in the module "Probability Theory and Statistics", facilitates the understanding of the lecture.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |                   |                                                          |



|                                                                                                                                                                                                                                            |            |                  |                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                            | 2,0        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001</li> <li>- C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006</li> </ul>                             |            |                  |                 |
|                                                                                                                                                                                                                                            | 2,0        | Seminar          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                          |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Vorlesungsfolien</li> <li>- R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001</li> <li>- C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006</li> </ul> |            |                  |                 |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                     |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Electromagnetic Compatibility in Automotive Systems |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2497050                                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                     | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the summer term                             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                                   | Institution       | Institut für Regelungstechnik                            |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4 / 5,0                                             | Module owner      | Prof. Dr. Thomas Form                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 56                                                  | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                     |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | oral exam or written exam (90 min)                  |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                     |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                     |                   |                                                          |
| <ul style="list-style-type: none"><li>- Electromagnetic environment and protection goals in the automotive sector;</li><li>- Sources of interference and coupling mechanisms;</li><li>- EMC-compliant power supply, vehicle electrical system architecture and power types;</li><li>- Measures to ensure EMC: grounding, shielding and filtering;</li><li>- EMC development process and test methods for vehicles and components, for conducted and radiated interference and ESD;</li><li>- EMC standards in the automotive sector and statutory EMC requirements;</li><li>- Product responsibility and liability</li></ul> |                                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                     |                   |                                                          |
| After completing this module, students will have basic knowledge of typical sources and sinks of electromagnetic interference in motor vehicles and will be familiar with the principles of coupling mechanisms of interference in the electrical system of a motor vehicle. The basics they have learned enable them to independently select basic EMC protection measures, analyse and evaluate their effectiveness and select and apply common procedures for testing EMC.                                                                                                                                                |                                                     |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                     |                   |                                                          |
| <ul style="list-style-type: none"><li>- M.I. Montrose; EMC and the printed Circuit Board - Design, Theory, and Layout made simple, IEEE-Press, ISBN: 978-0780347038</li><li>- V.P. Kodali; Engineering Electromagnetic Compatibility - Principles, Measurements, and Technologies, IEEE-Press, ISBN: 978-0780347434</li></ul>                                                                                                                                                                                                                                                                                                |                                                     |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                           |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                        | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                  | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <ul style="list-style-type: none"> <li>• M. I. Montrose, EMC and the printed Circuit Board - Design, Theory, and Layout made simple, IEEE-Press</li> <li>• V. P. Kodali; Engineering Electromagnetic Compatibility - Principles, Measurements, and Technologies, IEEE-Press</li> </ul>                                           |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                  | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <ul style="list-style-type: none"> <li>• M. I. Montrose, EMC and the printed Circuit Board - Design, Theory, and Layout made simple, IEEE-Press</li> <li>• V. P. Kodali; Engineering Electromagnetic Compatibility - Principles, Measurements, and Technologies, IEEE-Press</li> </ul>                                           |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                  | 1,0        | Excursion        | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <ul style="list-style-type: none"> <li>• M.I. Montrose, EMC and the printed Circuit Board - Design, Theory, and Layout made simple, IEEE-Press, ISBN: 978-0780347038</li> <li>• V.P. Kodali; Engineering Electromagnetic Compatibility - Principles, Measurements, and Technologies, IEEE-Press, ISBN: 978-0780347434</li> </ul> |            |                  |                 |

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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|-------------------|------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Automation of Industrial Manufacturing Processes                    |                   |                                                      |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2522610                                                             | Module version    |                                                      |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                     | Language          | german                                               |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the winter term                                             | Teaching unit     | Fakultät für Maschinenbau                            |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1                                                                   | Institution       | Institut für Werkzeugmaschinen und Fertigungstechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3 / 5,0                                                             | Module owner      | Prof. Dr. Klaus Dröder                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 150                                                                 |                   |                                                      |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 42                                                                  | Self studying (h) | 108                                                  |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                     |                   |                                                      |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | There are no requirements for this module.                          |                   |                                                      |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1 examination element: written exam (120 min) or oral exam (30 min) |                   |                                                      |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                     |                   |                                                      |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                     |                   |                                                      |
| <ul style="list-style-type: none"><li>• Analysis of industrial case studies and individual components (automotive industry, production of batteries and electronic components, and manufacturing processes for the aviation industry)</li><li>• Introduction to automated processes with an overview of the economic and overall significance, the definitions and technical terms</li><li>• Overview of hardware and devices used for automation</li><li>• Introduction to PLC especially regarding tasks and capabilities within automated processes</li><li>• Overview and operating principles of sensors and actuators with selected examples</li><li>• Insight into current and practical developments and their influence on the automation of industrial processes (Industry 4.0, Human-Robot-Collaboration (HRC))</li></ul> |                                                                     |                   |                                                      |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                     |                   |                                                      |
| Students... <ul style="list-style-type: none"><li>• are able to name automation technology devices (robot structures, control devices, transport systems, sensors, actuators...) and assign them to the respective scenarios (automotive, electronics and aviation industry).</li><li>• are able to classify the presented scenarios with regard to quantity, production costs and automation costs.</li><li>• gain the ability to analyse challenges arising in the scenarios and independently develop solutions based on the scenarios presented and transfer them to new problems.</li><li>• can use #Petri-Nets# to model complex process sequences in control systems.</li><li>• can use CFC programming (Continuous Function Chart) to perform simple control tasks.</li></ul>                                                |                                                                     |                   |                                                      |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                     |                   |                                                      |
| <ol style="list-style-type: none"><li>1. Lauber, R.; Göhner, P.: Prozessautomatisierung 2, Springer-Verlag, Berlin, Heidelberg, 1999</li><li>2. Favre-Bulle, B.: Automatisierung komplexer Industrieprozesse, Springer-Verlag, Wien, 2004</li><li>3. Gevatter H.J.: Automatisierungstechnik 2, Springer-Verlag, Berlin, Heidelberg, 2000</li><li>4. Bindel, T; Hofmann, D: Projektierung von Automatisierungsanlagen. Wiesbaden: Springer Fachmedien Wiesbaden, 2013</li></ol>                                                                                                                                                                                                                                                                                                                                                       |                                                                     |                   |                                                      |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 1,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                            |                   |                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|-------------------|----------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Modelling of Mechatronic Systems           |                   |                                  |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2540310                                    | Module version    |                                  |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                            | Language          | german                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the winter term                    | Teaching unit     | Fakultät für Maschinenbau        |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1                                          | Institution       | Institut für Akustik und Dynamik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3 / 5,0                                    | Module owner      | Prof. Dr. Michael Müller         |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 150                                        |                   |                                  |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 42                                         | Self studying (h) | 108                              |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                            |                   |                                  |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Requirements: No special requirements      |                   |                                  |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Written exa (90 min) or oral exam (30 min) |                   |                                  |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                            |                   |                                  |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                            |                   |                                  |
| Hamilton's Principle, Lagrange's equation of the second kind, Modeling of discrete mechanical systems, Analogies between mechanics and electrical systems, Modeling of discrete electrical systems, Modeling of mechatronic systems, actuators and sensors, Lagrange's equation of the first kind, constraint forces                                                                                                                                                                                                 |                                            |                   |                                  |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                            |                   |                                  |
| Students are able to apply a uniform approach to mathematically description of the dynamics of mechanical (multi-body) systems, electrical networks and mechatronic (electromechanical) systems. The use of different types of constraints can also be analysed and evaluated with regard to their solution behaviour. They can formulate and analyze equations of motion of selected mechatronic systems. They are thus able to independently develop and evaluate problem-adapted models for mechatronic problems. |                                            |                   |                                  |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                            |                   |                                  |
| <ul style="list-style-type: none"><li>• D. A. Wells, Lagrangian Dynamics, Schaum's Outlines, 1967</li><li>• R. H. Cannon, Dynamics of Physical Systems, Mc Graw Hill, 2003</li><li>• B. Fabian, Analytical System Dynamics, Springer, 2009</li></ul>                                                                                                                                                                                                                                                                 |                                            |                   |                                  |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                            |                   |                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                            |                   |                                  |

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| <b>Related courses</b>                 |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 2,0        | Lecture          | german          |
|                                        | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                         | Computer Networks 2 (MPO 2017)                                                        |                   |                                                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------|-------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                        | 4213390                                                                               | Module version    | V2                                              |
| Shorttext                                                                                                                                                                                                                                                                                     |                                                                                       | Language          | english german                                  |
| Frequency of offer                                                                                                                                                                                                                                                                            | only in the winter term                                                               | Teaching unit     | Carl-Friedrich-Gauß-Fakultät                    |
| Module duration                                                                                                                                                                                                                                                                               | 1                                                                                     | Institution       | Institut für Betriebssysteme und Rechnerverbund |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                         | 0 / 5,0                                                                               | Module owner      | Prof. Dr. Lars Wolf                             |
| Workload (h)                                                                                                                                                                                                                                                                                  | 150                                                                                   |                   |                                                 |
| Class attendance (h)                                                                                                                                                                                                                                                                          | 56                                                                                    | Self studying (h) | 94                                              |
| Compulsory requirements                                                                                                                                                                                                                                                                       |                                                                                       |                   |                                                 |
| Recommended requirements                                                                                                                                                                                                                                                                      | INF 2230 (Computer Networks) or equivalent knowledge                                  |                   |                                                 |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                  | 1 graded work: Written exam (90 minutes) or oral exam (20 minutes) or Take-Home-Exam. |                   |                                                 |
| Course achievement                                                                                                                                                                                                                                                                            |                                                                                       |                   |                                                 |
| Contents                                                                                                                                                                                                                                                                                      |                                                                                       |                   |                                                 |
| <div>- Internet protocols</div> <div>- IP</div> <div>- TCP</div> <div>- Routing methods</div> <div>- Newer protocols and methods</div>                                                                                                                                                        |                                                                                       |                   |                                                 |
| Objective qualification                                                                                                                                                                                                                                                                       |                                                                                       |                   |                                                 |
| On completion of this module, students will have deepened their knowledge from the course 'Computer Networks 1'. They will be familiar with the processes used on the Internet and the procedures involved.                                                                                   |                                                                                       |                   |                                                 |
| Literature                                                                                                                                                                                                                                                                                    |                                                                                       |                   |                                                 |
| Andrew Tanenbaum, David Wetherall, Nick Feamster, Computer Networks, 6.Ed. 2021, Print-ISBN: 978-1-292-37406-2, E-ISBN: 978-1-292-37401-7<br>James Kurose, Keith Ross. Computer Networking. A Top-Down Approach, 2021, 8th edition, Print-ISBN: 978-1-292-40546-9, E-ISBN: 978-1-292-40551-3. |                                                                                       |                   |                                                 |

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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                           |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                        | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                  | 4,0        | Lecture/Exercise | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <p>- Andrew S. Tanenbaum; David J. Wetherall: Computer Networks. International Edition. 5th edition. Pearson, 2010. ISBN-10: 0132553171 / ISBN-13: 9780132553179 - James F. Kurose; Keith W. Ross: Computer Networking: A Top-Down Approach. International Edition. 6th edition. Pearson, 2012. ISBN-10: 0273768964 / ISBN-13: 9780273768968</p> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                  | 2,0        | Exercise         | english         |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                      |                   |                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Robotics 2 - Programming, Modelling, Planning                                                                                                                                                                        |                   |                              |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4215450                                                                                                                                                                                                              | Module version    | V2                           |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                      | Language          |                              |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | only in the summer term                                                                                                                                                                                              | Teaching unit     | Carl-Friedrich-Gauß-Fakultät |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1                                                                                                                                                                                                                    | Institution       |                              |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 4 / 5,0                                                                                                                                                                                                              | Module owner      | Prof. Dr. Jochen Steil       |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 150                                                                                                                                                                                                                  |                   |                              |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 56                                                                                                                                                                                                                   | Self studying (h) | 94                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                      |                   |                              |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | The course assumes knowledge in mathematics as acquired in the introductory course in mathematics in the computer science curriculum. A previous attendance of the course “Robotics1” is strongly recommended.       |                   |                              |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | - Graded work: written exam (90 minutes) or oral exam (about 20 minutes) or Take-Home-Exam. The form of the examination depends on the number of participants and will be announced at the beginning of the lecture. |                   |                              |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                      |                   |                              |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                      |                   |                              |
| Relying on the fundamental concepts of the course “Robotics1”, the course “Robotics2” offers a focus on more practical issues arising in the control if robotic systems. This includes in particular:<br>- Principles of perception and measurments and robot sensing<br>- Techniques of modeling and simulation<br>- Paradigms and best practices of robot programming<br>- Specification of robotic tasks<br>- Planning method of robotic actions<br>- Techniques for the study of work space and singularities<br>- Distinction of rigid and elastic components<br>- Advances techniques for controlling robotic systems<br>- Combinatorial modeling of mechanical systems                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                      |                   |                              |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                      |                   |                              |
| The course conveys basic computer science paradigms, concepts, algorithms of robotics to the students. After a successful completion of the course, the acquired knowledge offers a solid foundation that enables the students to realize advanced robot applications in diverse technological fields. In particular, the students gain following competences:<br>- Deepened understanding of essential, theoretical foundations of robotics<br>- Broadened knowledge of practical tasks for running robots<br>- Further pervasion of a systemic, model-based approach to robotics<br>- Perception of a robot as a technical system for motion and force generation<br>- Deepened comprehension of properties of spatial motions<br>- Expansion of programming competences<br>- Increased ability to reflect on programming activities<br>- Qualification for evaluation of computational and geometrical tasks in robotics as well as of algorithms for solving them |                                                                                                                                                                                                                      |                   |                              |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                      |                   |                              |
| - P.J. McKerrow: Introduction to Robotics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                      |                   |                              |

- Spong, Hutchinson, Vidyasagar, 'Robot Modeling and Control', 2005.

Scripts, slides, and further references are announced in the course



#### Related courses

#### Rules for the choice of courses

#### Compulsory attendance

| Name of the course | SWS | Eventtype | Language |
|--------------------|-----|-----------|----------|
|--------------------|-----|-----------|----------|

|            |     |                  |                |
|------------|-----|------------------|----------------|
| Robotics 2 | 4,0 | Lecture/Exercise | english german |
|------------|-----|------------------|----------------|

#### Literature

- P.J. McKerrow: "Introduction to Robotics". Addison-Wesley (div. Exemplare in UB)
- R.M. Murray, Z. Li, S.S. Sastry: "A Mathematical Introduction to Robotic Manipulation". (online)
- K.M. Lynch, F.C. Park: "Modern Robotics: Mechanics, Planning, and Control". (online)

Scripts, slides, and further references are announced in the course.

| Title                                                                                                                                                                                                                                                                                                                                                                                                       | Robotics 1 - Technical and Mathematical Basics                                                                                                                                                                 |                   |                              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                      | 4215460                                                                                                                                                                                                        | Module version    | V2                           |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                | Language          |                              |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                | Teaching unit     | Carl-Friedrich-Gauß-Fakultät |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                             | 1                                                                                                                                                                                                              | Institution       |                              |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                       | 4 / 5,0                                                                                                                                                                                                        | Module owner      |                              |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                | 150                                                                                                                                                                                                            |                   |                              |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                        | 56                                                                                                                                                                                                             | Self studying (h) | 94                           |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                |                   |                              |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                | 1 graded work: Written exam (90 minutes) or oral exam (20 minutes) or Take-Home-Exam. The form of the examination depends on the number of participants and will be announced at the beginning of the lecture. |                   |                              |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                |                   |                              |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                |                   |                              |
| They are able to<br><br>- understand and correctly apply basic concepts of medical robotics<br>- model manipulators and describe them in geometrical and mathematical terms<br>- compute kinematic transforms<br>- compute and analyze the Jacobian, including singularities and redundancy<br>- compute differential kinematics and use these in control settings<br>- apply and judge planning algorithms |                                                                                                                                                                                                                |                   |                              |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                |                   |                              |
|                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                |                   |                              |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                |                   |                              |
| With successful completion of the module, the students possess knowledge of the technical and mathematical foundations in robotics. They have the basic knowledge to enter advanced studies and are able to apply their knowledge for the analysis and realization of simple robotic applications                                                                                                           |                                                                                                                                                                                                                |                   |                              |



|                                        |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Related courses</b>                 |     |           |          |
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|                                                                                                                                                          |     |                  |                |
|----------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------------|----------------|
| Robotics 1 - Technical and Mathematical Basics                                                                                                           | 4,0 | Lecture/Exercise | english german |
| <b>Literature</b>                                                                                                                                        |     |                  |                |
| - P.J. McKerrow: Introduction to Robotics, Addison-Wesley (div. Exemplare in UB) - Vorlesungsumdrucke - further information will be given in the lecture |     |                  |                |
|                                                                                                                                                          | 2,0 | Exercise         | english german |

|                                                                                                                                                                                                                                                                                                 |                                                      |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                           | Computer Architecture 1                              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                          | 2416010                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                       |                                                      | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                              | only in the winter term                              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                 | 1                                                    | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                           | 4 / 6,0                                              | Module owner      | Prof. Dr. Selma Saidi                                    |
| Workload (h)                                                                                                                                                                                                                                                                                    | 180                                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                            | 56                                                   | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                       | Written exam (120 minutes) or oral exam (30 minutes) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                              |                                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                        |                                                      |                   |                                                          |
| <ul style="list-style-type: none"><li>• Introduction to computer architecture</li><li>• Principles of computer architecture (control, pipelining, memory hierarchy)</li><li>• Microprocessors (RISC, ISC)</li><li>• Quantitative computer design</li><li>• Design of instruction sets</li></ul> |                                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                         |                                                      |                   |                                                          |
| Students have basic knowledge of modern computer architectures and an understanding of the function of modern computers. With the knowledge they have acquired, they are able to configure computer systems on a component basis and evaluate their performance.                                |                                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                      |                                                      |                   |                                                          |
| D. Patterson, J. L. Hennessy, Computer Organization and Design #– The Hardware/Software Interface, Morgan Kaufmann Publishers, ISBN 978-0-12-370606-5 #<br>W. Stallings, Computer Organization & Architecture, 6. Edition, Prentice Hall, ISBN-13: 978-0-13-035119-7 #<br>Lecture notes         |                                                      |                   |                                                          |

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|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                        | 1,0        | Exercise         | german          |
|                                        | 3,0        | Lecture          | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Low power CMOS data converter circuit design |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2420210                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | irregular                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                            | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                      | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 36                                           | Self studying (h) | 114                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Oral exam (30 min)                           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| <p>Data converters bridge digital virtual space and analog real world in cyber physical system (CPS), and become key building circuit blocks. This lecture deals with the circuit design of CMOS data converters. In particular, circuit techniques related to low-power and high-resolution ADCs, which are important for sensor signal detection in IoT application, will be explained. It is assumed that the students have basic knowledge of CMOS integrated circuit design and signal processing such as Laplace transform and Z transform.</p> <p>General introduction of data converters</p> <p>1. Data converter application areas</p> <p>Sensor interface, Communication (wireless/wireline)</p> <p>2. Basic theory in data conversion</p> <p>Sampling/Quantization, Performance metric (INL/DNL, SNDR, SFDR, ENOB, FoM)</p> <p>3. Architectures and features of data converters</p> <p>2-1. High resolution data converter (SAR, ##, VCO based)</p> <p>2-2. High speed data converter (Flash, Pipeline)</p> <p>Implementation of low-power and high-resolution CMOS integrated ADCs</p> <p>4. Building blocks of ADC</p> <p>Comparator, operational amplifier</p> <p>5. SAR-ADC with charge redistribution.</p> <p>3-1. Power reduction techniques</p> <p>3-2. Resolution enhancement techniques (digital calibration etc.)</p> <p>6. High resolution ## modulator</p> <p>7. Time based (VCO based) ADC</p> <p>8. Hybrid-ADC</p> <p>9. Characterization of data converters</p> |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                              |                   |                                                          |

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| Related courses                 |     |              |          |
|---------------------------------|-----|--------------|----------|
| Rules for the choice of courses |     |              |          |
|                                 |     |              |          |
| Compulsory attendance           |     |              |          |
|                                 |     |              |          |
| Name of the course              | SWS | Eventtype    | Language |
|                                 | 3,0 | Block course | english  |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Low-Power Embedded Systems             |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2416000000                             | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                        | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the winter term                | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                      | Institution       | Institut für Datentechnik und Kommunikationsnetze        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 3 / 5,0                                | Module owner      | Prof. Dr. Andres Gomez                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                    |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 42                                     | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                        |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Written (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                        |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                        |                   |                                                          |
| <ul style="list-style-type: none"><li>• An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is designed for a specific function or for specific functions within a larger system. For example, they are part of industrial machines, agricultural and process industry devices, automobiles, medical equipment, cameras, household appliances, airplanes, sensor networks, internet-of-things, as well as mobile devices.</li><li>• The focus of this lecture is on the design of low-power embedded systems using formal models and utilizing the latest micro-architectural features for improved performance and energy efficiency, with practical examples using C/C++.</li></ul> |                                        |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                        |                   |                                                          |
| The students <ul style="list-style-type: none"><li>• gain an understanding of specific requirements, issues, and performance evaluations of low-power embedded system applications.</li><li>• make design decisions with deep knowledge of the inherent cost-versus-performance trade-offs in low-power, resource-constrained systems.</li><li>• apply the principles of real-time operating systems and scheduling theory to design efficient applications with shared resources.</li><li>• analyze different architectures, evaluate their hardware-software interface and memory architecture and different optimization techniques for microcontrollers, such as DSP extensions to the instruction set architecture.</li></ul>                           |                                        |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                        |                   |                                                          |
| <ul style="list-style-type: none"><li>- Edward A. Lee and Sanjit A. Seshia: Introduction to Embedded Systems, A Cyber- Physical Systems Approach, Second Edition, MIT Press, ISBN 978- 0-262-53381-2, 2017.</li><li>- P. Marwedel: Embedded System Design, Springer, ISBN 978- 3-030-60909-2, 2021.</li><li>- G.C. Buttazzo: Hard Real- Time Computing Systems. Springer Verlag, ISBN 978- 1-4614-0676-1, 2011.</li><li>- M. Wolf: Computers as Components – Principles of Embedded System Design. Morgan Kaufman Publishers, ISBN 978-0-128-05387-4, 2016.</li><li>- Avelino J. Gonzalez: Computer Programming in C for Beginners, Springer, ISBN 978-3-030-50752-7, 2020.</li></ul>                                                                        |                                        |                   |                                                          |

- Joseph Yiu. The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors. Newnes, 2013.



| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |           |          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----------|----------|
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |           |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |     |           |          |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |     |           |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |     |           |          |
| Name of the course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | SWS | Eventtype | Language |
| Low-Power Embedded Systems                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2,0 | Lecture   | english  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |           |          |
| <ul style="list-style-type: none"> <li>- Edward A. Lee and Sanjit A. Seshia: Introduction to Embedded Systems, A Cyber-Physical Systems Approach, Second Edition, MIT Press, ISBN 978- 0-262-53381-2, 2017.</li> <li>- P. Marwedel: Embedded System Design, Springer, ISBN 978- 3-030-60909-2, 2021.</li> <li>- G. C. Buttazzo: Hard Real-Time Computing Systems. Springer Verlag, ISBN 978- 1-4614-0676-1, 2011.</li> <li>- M. Wolf: Computers as Components – Principles of Embedded System Design. Morgan Kaufman Publishers, ISBN 978-0-128-05387-4, 2016.</li> <li>- Avelino J. Gonzalez: Computer Programming in C for Beginners, Springer, ISBN 978-3-030-50752-7, 2020.</li> <li>- Joseph Yiu. The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors. Newnes, 2013.</li> </ul> |     |           |          |
| Low-Power Embedded Systems                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1,0 | Exercise  | english  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |           |          |
| <ul style="list-style-type: none"> <li>- Edward A. Lee and Sanjit A. Seshia: Introduction to Embedded Systems, A Cyber-Physical Systems Approach, Second Edition, MIT Press, ISBN 978- 0-262-53381-2, 2017.</li> <li>- P. Marwedel: Embedded System Design, Springer, ISBN 978- 3-030-60909-2, 2021.</li> <li>- G. C. Buttazzo: Hard Real-Time Computing Systems. Springer Verlag, ISBN 978- 1-4614-0676-1, 2011.</li> <li>- M. Wolf: Computers as Components – Principles of Embedded System Design. Morgan Kaufman Publishers, ISBN 978-0-128-05387-4, 2016.</li> <li>- Avelino J. Gonzalez: Computer Programming in C for Beginners, Springer, ISBN 978-3-030-50752-7, 2020.</li> <li>- Joseph Yiu. The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors. Newnes, 2013.</li> </ul> |     |           |          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Hardware Software Codesign                                                                                                                                                               |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2416000010                                                                                                                                                                               | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                          | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the winter term                                                                                                                                                                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                                                                                                                                                                        | Institution       | Institut für Computer Engineering                        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 6,0                                                                                                                                                                                  | Module owner      | Prof. Dr. Selma Saidi                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 180                                                                                                                                                                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                                                                                                                                                                                       | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Basic knowlesge of computer architectures and programming language C                                                                                                                     |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1. Written exam (max 180 min) or oral exam (max 40 min)<br>2. Project work incl. written reports<br><br>The overall grade is the arithmetic average of the grades of components 1 and 2. |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                          |                   |                                                          |
| 1. Design of mixed Hardware/Software solutions for embedded systems<br>2. Understanding of design components<br>3. Understanding of system-level design paradigms<br>4. HW/SW partitioning<br>5. Optimization methods<br>6. Performance analysis measures<br>7. Evaluation methods<br>8. Modelling and Performance analysis of safety-critical and real-time embedded systems.                                                                                                                                                                                                   |                                                                                                                                                                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                          |                   |                                                          |
| The students know the basic design of complex electronic systems at high level of abstractions. This includes the optimized partitioning, scheduling and evaluation of mixed hardware and software design solutions dedicated to embedded systems. The students understand about advanced related topics in HW/SW codesign and performance analysis for safety critical and real-time embedded systems. Starting from simple system specification the students can use tools for partitioning, optimization and performance analysis to synthesize the hardware/software system. |                                                                                                                                                                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                          |                   |                                                          |
| [1] „Specification and Design of Embedded Systems“, D. Gajski, Prentice Hall 1994, ISBN 0-13-150731-1<br>[2] „Digitale Hardware/Software Systeme – Synthese und Optimierung“, J. Teich, Springer Verlag 1997, ISBN 3-540-62433-3                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                          |                   |                                                          |

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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                           |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                           |            |                  |                 |
|                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                  |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                        | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Hardware Software Codesign                                                                                                                                                                                                       | 3,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                |            |                  |                 |
| [1] „Specification and Design of Embedded Systems“, D. Gajski, Prentice Hall 1994, ISBN 0-13-150731-1<br>[2] „Digitale Hardware/Software Systeme – Synthese und Optimierung“, J. Teich, Springer Verlag 1997, ISBN 3-540-62433-3 |            |                  |                 |
| Hardware Software Codesign                                                                                                                                                                                                       | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                |            |                  |                 |
| [1] „Specification and Design of Embedded Systems“, D. Gajski, Prentice Hall 1994, ISBN 0-13-150731-1<br>[2] „Digitale Hardware/Software Systeme – Synthese und Optimierung“, J. Teich, Springer Verlag 1997, ISBN 3-540-62433-3 |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Embedded Autonomy                                                                                                                                                                       |                   |                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2416000020                                                                                                                                                                              | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                         | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | only in the summer term                                                                                                                                                                 | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1                                                                                                                                                                                       | Institution       | Institut für Computer Engineering                        |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 4 / 6,0                                                                                                                                                                                 | Module owner      | Prof. Dr. Selma Saidi                                    |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 180                                                                                                                                                                                     |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 56                                                                                                                                                                                      | Self studying (h) | 124                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                         |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1. Written exam (max 90 min) or oral exam (max 30 min)<br>2. Project work incl. written reports<br><br>The overall grade is the arithmetic average of the grades of components 1 and 2. |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                         |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                         |                   |                                                          |
| <ul style="list-style-type: none"><li>• Requirements on functional safety</li><li>• Providing and preserving trustworthiness in Autonomous Systems</li><li>• System Architectures and Platforms for Autonomous Systems</li><li>• Verification of Autonomous Systems</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                         |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                         |                   |                                                          |
| The students will get basic knowledge in the platforms used in autonomous systems as well as very recent fields required to the design of safe autonomous systems considering functional and non-functional aspects (e.g. safety, reliability). The students learn to implement simple autonomous systems tasks (Sensor fusion and AI computation which pose special demands on the architectures in order to implement the Perceive - Decide - Act loop) on embedded platforms. The students can balance the performance limitations of the platform against the complexity of tasks and therefore find an optimal utilization of the resources.                                                        |                                                                                                                                                                                         |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                         |                   |                                                          |
| Christopher Rouff: "Autonomous and Autonomic Systems: With Applications to NASA Intelligent Spacecraft Operations and Exploration Systems" (NASA Monographs in Systems and Software Engineering). Springer-Verlag, Berlin, Heidelberg, 2007.<br>Samuel Kounev, Jeffrey O. Kephart, Aleksandar Milenkoski, and Xiaoyun Zhu: „Self-Aware Computing Systems". Springer Publishing Company, Incorporated, 1st edition, 2017.<br>Defense Advanced Research Projects Agency (DARPA). Broad Agency Announcement - Assured Autonomy, August 2017<br>Selma Saidi, Dirk Ziegenbein, Jyotirmoy V. Deshmukh, Rolf Ernst: "Autonomous Systems Design: Charting a New Discipline", IEEE Design and Test Magazine 2021. |                                                                                                                                                                                         |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Embedded Autonomy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <p>Christopher Rouff: "Autonomous and Autonomic Systems: With Applications to NASA Intelligent Spacecraft Operations and Exploration Systems" (NASA Monographs in Systems and Software Engineering). Springer-Verlag, Berlin, Heidelberg, 2007.</p> <p>Samuel Kounev, Jeffrey O. Kephart, Aleksandar Milenkoski, and Xiaoyun Zhu: „Self-Aware Computing Systems". Springer Publishing Company, Incorporated, 1st edition, 2017.</p> <p>Defense Advanced Research Projects Agency (DARPA). Broad Agency Announcement - Assured Autonomy, August 2017</p> <p>Selma Saidi, Dirk Ziegenbein, Jyotirmoy V. Deshmukh, Rolf Ernst: "Autonomous Systems Design: Charting a New Discipline", IEEE Design and Test Magazine 2021.</p> |            |                  |                 |
| Embedded Autonomy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <p>Christopher Rouff: "Autonomous and Autonomic Systems: With Applications to NASA Intelligent Spacecraft Operations and Exploration Systems" (NASA Monographs in Systems and Software Engineering). Springer-Verlag, Berlin, Heidelberg, 2007.</p> <p>Samuel Kounev, Jeffrey O. Kephart, Aleksandar Milenkoski, and Xiaoyun Zhu: „Self-Aware Computing Systems". Springer Publishing Company, Incorporated, 1st edition, 2017.</p> <p>Defense Advanced Research Projects Agency (DARPA). Broad Agency Announcement - Assured Autonomy, August 2017</p> <p>Selma Saidi, Dirk Ziegenbein, Jyotirmoy V. Deshmukh, Rolf Ernst: "Autonomous Systems Design: Charting a New Discipline", IEEE Design and Test Magazine 2021.</p> |            |                  |                 |

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|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|---------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Automation Engineering with Laboratory                                                                                                                                                                                                                                                                                                                           |                   |                                                         |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2539000060                                                                                                                                                                                                                                                                                                                                                       | Module version    |                                                         |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                  | Language          | english                                                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                                                                                                                                                                                                                                                                                                                                          | Teaching unit     | Fakultät für Maschinenbau                               |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                                                                                                                                                                                                                                                                                                                                | Institution       | Institut für Intermodale Transport- und Logistiksysteme |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 6 / 7,0                                                                                                                                                                                                                                                                                                                                                          | Module owner      | Prof. Dr. Jürgen Pannek                                 |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 210                                                                                                                                                                                                                                                                                                                                                              |                   |                                                         |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 56                                                                                                                                                                                                                                                                                                                                                               | Self studying (h) | 154                                                     |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                  |                   |                                                         |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Control Engineering                                                                                                                                                                                                                                                                                                                                              |                   |                                                         |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 examination elment: written exam+ (90 min) or oral exam+ (30 min)                                                                                                                                                                                                                                                                                              |                   |                                                         |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2 course achievements:<br>a) optional course achievement: Creation and documentation of a computer or software program (on request, the result of the coursework within the framework of the exam+ is included in the assessment at 20%)<br>b) Compulsory course achievement: colloquium or report (organized in groups) on the completed laboratory experiments |                   |                                                         |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                  |                   |                                                         |
| Lecture/Tutorial: <ul style="list-style-type: none"><li>• Aim of automation engineering</li><li>• Basics, tasks and methods of automation</li><li>• Coupling and hierarchies of systems</li><li>• Information and information management</li><li>• Control, modularization and standardization in automation</li><li>• Digitalization for industrial internet, industrial cloud and CPS</li><li>• Basics of knowledge management, industrial big data and decision support</li></ul> Laboratory: <ul style="list-style-type: none"><li>• Computer-aided design of an automation system</li><li>• Realization of an automation task with a PLC</li><li>• Modelling and simulation of robots</li><li>• Robot programming</li><li>• NC programming - production of a turned part</li><li>• Control of an automated guided vehicle (AGV)</li></ul> |                                                                                                                                                                                                                                                                                                                                                                  |                   |                                                         |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                  |                   |                                                         |
| After having successfully completed the lecture Automation Engineering, the students will have a sound basic knowledge of term and methods within the area of automation engineering and are able to reproduce, describe and apply the latter. The students can explain modeling, classification, control and coupling of                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                  |                   |                                                         |

technical processes. They are also able to analyze information handling in technical processes and information transfer. Students are capable to determine the organizational, distribution and communication structures of automation systems. In addition, the students can describe basic aspects of modularization, standardization, and automation. The students understand the digitization topics industrial internet, cloud and cyber-physical systems. As such, the students can reproduce the approaches of knowledge management, industrial big data, and decision support. The laboratory enables students to independently apply the acquired skills to simple, practical tasks in various automation domains.

#### Literature

- Lunze, J.: Automatisierungstechnik. 5. Auflage. DeGruyter (2020);
- Plenk, V.: Grundlagen der Automatisierungstechnik kompakt, Springer (2019);
- Lai, C.: Intelligent Manufacturing, Springer (2022);
- Langmann, C.; Turi, D.: Robotic process automation – Digitalisierung und Automatisierung von Prozessen, Springer (2020);
- Stjepandic, J.; Sommer, M.; Denkena, B.: DigiTwin: An approach for production process optimization in a built environment, Springer (2022)



#### Related courses

##### Rules for the choice of courses

##### Compulsory attendance

| Name of the course     | SWS | Eventtype  | Language |
|------------------------|-----|------------|----------|
| Automation Engineering | 2,0 | Laboratory | english  |
| Automation Engineering | 2,0 | Lecture    | english  |
| Automation Engineering | 2,0 | Exercise   | english  |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Gallium Nitride Technology                  |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2413000030                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                     | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| <p>The course builds on 'Lighting Technology I'. While Lighting Technology I focusses on general questions of lighting and lighting technology, this course discusses LED technology and gallium nitride technology in particular:</p> <ul style="list-style-type: none"><li>• Physical principles of LEDs. Band gap engineering in LEDs.</li><li>• Semiconductor materials for optoelectronics</li><li>• Relationship between material properties and LED properties</li><li>• Manufacturing processes</li><li>• Efficiency considerations</li><li>• Front-end and back-end processing</li><li>• Application examples in general lighting, automotive technology, sensor technology</li><li>• Infrared LEDs, visible light, UV LEDs</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| After completing the module, students will have an overview of the current state of LED technology and the development opportunities that solid state lighting will offer in the future. In addition, they will have a basic understanding of the physical processes within LEDs.                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |



| <b>Related courses</b>                 |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Gallium Nitride Technology             | 2,0        | Lecture          | german          |
| Gallium Nitride Technology             | 1,0        | Exercise         | german          |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                   |                   |                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Industrial Robots with Laboratory                                                                                                 |                   |                                                      |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2522560                                                                                                                           | Module version    |                                                      |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                   | Language          | german                                               |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | only in the winter term                                                                                                           | Teaching unit     | Fakultät für Maschinenbau                            |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1                                                                                                                                 | Institution       | Institut für Werkzeugmaschinen und Fertigungstechnik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 4 / 7,0                                                                                                                           | Module owner      | Prof. Dr. Klaus Dröder                               |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 210                                                                                                                               |                   |                                                      |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 56                                                                                                                                | Self studying (h) | 154                                                  |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                   |                   |                                                      |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Requirements: Basic knowledge of engineering mechanics, vector and matrix calculus, differential calculus and control engineering |                   |                                                      |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1 examination element: written exam (120 min) or oral exam (30 min)                                                               |                   |                                                      |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1 course achivement: protocol of the laboratory experiments                                                                       |                   |                                                      |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                   |                   |                                                      |
| <ul style="list-style-type: none"><li>• Introduction: History, groups of robots, fields of apply</li><li>• Structure-development: degrees of freedom, joints, serial and parallel structures, structure of a robot</li><li>• Programming: Types of programming, languages of programming (especially KRL)</li><li>• Kinematic: Elementary-transformation, kinematic robot-model, types of calculation, singularities</li><li>• Dynamic and bearing-control: dynamic robot model, calculation of forces and moments, types of bearing-control</li><li>• Control: Creation of movement, structure, sensor integration</li></ul>                                                                                                                                                                                                                                 |                                                                                                                                   |                   |                                                      |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                   |                   |                                                      |
| Students... <ul style="list-style-type: none"><li>• have the ability to differentiate between serial and parallel structures and to divide the robot into main and secondary axes.</li><li>• are able to analyze workspaces and designs and will be able to evaluate them with regard to application criteria.</li><li>• will be able to explain components of the robot.</li><li>• are able to explain and calculate kinematic and dynamic models of different robots.</li><li>• are able to name the control approaches and device-related structures required for the control system, and to apply textual and graphic-interactive programming forms.</li><li>• are able to identify structure-specific problems and develop solution strategies.</li><li>• can place themselves in a group, contribute to the solution and present the results.</li></ul> |                                                                                                                                   |                   |                                                      |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                   |                   |                                                      |
| <ul style="list-style-type: none"><li>• Lenarcic, J.; Parenti V.: Advances in Robot Kinematics 2018. Springer, Berlin, 2018</li><li>• Appleton, E.; Williams, D. J.: Industrieroboter: Anwendungen. VCH: Weinheim, New York, Basel, Cambridge, 1991</li><li>• Knoll, A.; Christaller, T.: Robotik. Fischer, Frankfurt, November 2003</li><li>• Siciliano, B.; Khatib, O.: Springer Handbook of Robotics, Springer Verlag, Berlin, 2008</li><li>• Volmer, J.: Industrieroboter - Funktion und Gestaltung. Verl. Technik: Berlin. 1992</li></ul>                                                                                                                                                                                                                                                                                                                |                                                                                                                                   |                   |                                                      |

- Weber, W.: Industrieroboter. Carl Hanser Verlag: München, Wien, 2019



| <b>Related courses</b>                 |     |            |          |
|----------------------------------------|-----|------------|----------|
| <b>Rules for the choice of courses</b> |     |            |          |
|                                        |     |            |          |
| <b>Compulsory attendance</b>           |     |            |          |
|                                        |     |            |          |
| Name of the course                     | SWS | Eventtype  | Language |
|                                        | 2,0 | Lecture    | german   |
|                                        | 1,0 | Exercise   | german   |
|                                        | 2,0 | Laboratory | german   |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                     |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | AI Engineering                                                                                                                                                                      |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2424000050                                                                                                                                                                          | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                     | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the winter term                                                                                                                                                             | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                                                                                                                                                                   | Institution       | Institut für Nachrichtentechnik                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                                                                                                                                                             | Module owner      | Prof. Dr. Tim Fingscheidt                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                                                                                                                                                                 |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                                                                                                                                                                                  | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Basic knowledge (in theory and practice) in machine learning is required, e.g. from-Mustererkennung / Pattern Recognition (2424102) und im Computerlabor Mustererkennung (2424133). |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Written exam (120 min) or roal exam (30 min)                                                                                                                                        |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Lab work                                                                                                                                                                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                     |                   |                                                          |
| <div>- Foundation Models</div> <div>- Prompt Engineering</div> <div>- Retrieval-Augmented Generation</div> <div>- Agents</div> <div>- Finetuning</div> <div>- Legal and Ethical Aspects</div> <div>- Building Applications with Foundation Models</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                     |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                     |                   |                                                          |
| Students are able to explain the structure, functionality, and application of foundation models (large, generally pre-trained AI models) and describe their core components such as tokenization, embeddings, transformer architectures, and training procedures. They can apply methods such as prompt engineering, retrieval-augmented generation, finetuning, and agent systems to adapt AI models to specific tasks. Furthermore, they are able to analyze technical concepts, select appropriate tools, and design and evaluate AI applications while considering legal and ethical frameworks. In the accompanying lab sessions, students implement and experiment with the presented methods in practice, thereby deepening their understanding through hands-on experience. |                                                                                                                                                                                     |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                     |                   |                                                          |
| <div>- Lecure slides</div> <div>- Publications on key technologies</div> <div>- C. Huyen: „AI Engineering“, O'Reilly Media, 2025</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                     |                   |                                                          |



|                                                                                                                                                                                    |            |                  |                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                             |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                             |            |                  |                 |
|                                                                                                                                                                                    |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                       |            |                  |                 |
|                                                                                                                                                                                    |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                          | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| AI Engineering                                                                                                                                                                     | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                  |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Vorlesungsfolien</li> <li>- Publikationen zu Schlüsseltechnologien</li> <li>- C. Huyen: „AI Engineering“, O'Reilly Media, 2025</li> </ul> |            |                  |                 |
| Computer Lab AI Engineering                                                                                                                                                        | 2,0        | Internship       | english         |
| <b>Literature</b>                                                                                                                                                                  |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Lecure slides</li> <li>- Publications on key technologies</li> <li>- C. Huyen: „AI Engineering“, O'Reilly Media, 2025</li> </ul>          |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Verification, Validation and Testing of ASIC Designs |                   |                                      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------|--------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 4211500                                              | Module version    |                                      |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                      | Language          | english                              |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the summer term                              | Teaching unit     |                                      |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                                    | Institution       | Institut für Theoretische Informatik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                              | Module owner      | Prof. Dr. Guillermo Payá Vayá        |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                                  |                   |                                      |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                                                   | Self studying (h) | 94                                   |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                      |                   |                                      |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | graded work (examination): oral exam (30 minutes)    |                   |                                      |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                      |                   |                                      |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                      |
| 1. Einführung in Verifikation, Validierung und Testing 2. Pre-Silicon Verifikation 2.1 Einführung in ASIC Design Verifikation 2.2 Herangehensweisen zu funktionaler Verifikation 2.3 Verifikationswerkzeuge 2.4 Verifikation Strategien 2.5 Design for Reuse 3. Post-Silicon Validierung 3.1 Einführung in ASIC Validierung 3.2 Traditionelle Post-Silicon Validierung (in der Industrie) 3.3 Reversi Test Generation System 4. Run-Time Verifikation 4.1 Motivation für Laufzeit-Verifikation 4.2 Klassifikation von Laufzeit-Verifikationslösungen 4.3 Dynamische Implementierung von Verifikations- Architekturen 4.4 Run-time Verifikation von einfachen Cores 4.5 Hardware Patching Herangehensweisen 5. Testing 5.1 Einführung zu VLSI Testing 5.2 Design for Testability 5.3 Test Generation |                                                      |                   |                                      |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                      |                   |                                      |
| Die Studierenden lernen Techniken zur Verifikation, Validierung und dem Testen von ASIC-Designs kennen. Auf Basis von praktischen Beispielen und aktuellen Entwicklungswerkzeugen werden die Studierenden an Herausforderungen der heutigen Chipentwicklung und dem Testen herangeführt.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                      |                   |                                      |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                      |                   |                                      |
| - Wagner and Bertacco (2011): "Post-Silicon and Runtime Verification for Modern Processors" - Wang, Stroud, and Touba (2008): "System-on-Chip Test Architectures: Nanometer Design for Testability" - Mishra and Dutt (2005): "Functional Verification of Programmable Embedded Architectures: A Top-Down Approach" - Haque, Khan, and Michelson (2001): "The Art of Verification with VERA" - Keating and Bricaud (1999): "Reuse Methodology Manual" - Bergeron (2000): "Writing Testbenches. Functional Verification of HDL Models"                                                                                                                                                                                                                                                               |                                                      |                   |                                      |
| Further references will be announced in the course.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                      |                   |                                      |



| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Verification, Validation and Testing of ASIC Designs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4,0        | Lecture/Exercise | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |
| <p>- Wagner and Bertacco (2011): "Post-Silicon and Runtime Verification for Modern Processors" - Wang, Stroud, and Toubia (2008): "System-on-Chip Test Architectures: Nanometer Design for Testability" - Mishra and Dutt (2005): "Functional Verification of Programmable Embedded Architectures: A Top-Down Approach" - Haque, Khan, and Michelson (2001): "The Art of Verification with VERA" - Keating and Bricaud (1999): "Reuse Methodology Manual" - Bergeron (2000): "Writing Testbenches. Functional Verification of HDL Models" Weitere Referenzen werden in der Veranstaltung bekannt gegeben.</p> |            |                  |                 |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                             |                   |                               |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Memory Systems                                                                                              |                   |                               |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 4211460                                                                                                     | Module version    | V2                            |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                             | Language          | english                       |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the summer term                                                                                     | Teaching unit     | Carl-Friedrich-Gauß-Fakultät  |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                                                                                                           | Institution       |                               |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 4 / 5,0                                                                                                     | Module owner      | Prof. Dr. Guillermo Payá Vayá |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                                                                                                         |                   |                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 56                                                                                                          | Self studying (h) | 94                            |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                             |                   |                               |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | The module “Application-Specific Instruction-Set Processors” is recommended as preparation for this course. |                   |                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Graded work (examination): Written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam.           |                   |                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                             |                   |                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                             |                   |                               |
| 1. Introduction to Memory Systems (Review)<br>2. Overview on Memory Technology<br>2.1 Volatile Memories: SRAM, DRAM<br>2.2 Non-volatile Memories: ROM, Flash Memory, F-RAM, MRAM,...<br>3. Main Memory: Interfaces, Commands, and Controllers<br>4. Memory Cache<br>5. Processing-in-Memory (PIM) / New Data Processing<br>5.1 Using traditional and 3D-Stacked memories<br>5.2 Low-latency interfaces                                                                                                                                                                                      |                                                                                                             |                   |                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                             |                   |                               |
| This course focusses on the main challenges for the design of modern semiconductor storage systems under the aspect of rapidly growing data storage requirements. Current, volatile and non-volatile memory types will be covered from the fundamental semiconductor technology level up to higher levels of system-level abstraction, with a focus on reliability and protection of stored data. Furthermore, Processing-in-Memory Architectures (PIM) based on conventional and 3D-stacked memories are analyzed, taking into account aspects such as low latency and energy consumption. |                                                                                                             |                   |                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                             |                   |                               |
| • Balasubramonian (2019): "Innovations in the Memory Systems", Morgen & Claypool Publishers<br>• Hennessy and Patterson (2017): "Computer Architecture. A Quantitative Approach", 6th Edition, Morgan Kaufmann<br>• Jacob, Ng, and Wang (2008): "Memory Systems: Cache, DRAM, Disk", Morgan Kaufmann "                                                                                                                                                                                                                                                                                      |                                                                                                             |                   |                               |
| Further references will be announced in the course.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                             |                   |                               |



|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Memory Systems                                                                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Balasubramonian (2019): "Innovations in the Memory Systems", Morgan &amp; Claypool Publishers</li> <li>- Hennessy and Patterson (2017): "Computer Architecture. A Quantitative Approach", 6th Edition, Morgan Kaufmann</li> <li>- Jacob, Ng, and Wang (2008): "Memory Systems: Cache, DRAM, Disk", Morgan Kaufmann "</li> </ul> <p>Further references will be announced in the course.</p> |            |                  |                 |
| Memory Systems                                                                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Exercise         | english         |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                              |                   |                               |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Advanced FPGA-Design                                                                                                                         |                   |                               |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4211510                                                                                                                                      | Module version    | V2                            |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                              | Language          | english german                |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | only in the winter term                                                                                                                      | Teaching unit     | Carl-Friedrich-Gauß-Fakultät  |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1 Semester                                                                                                                                   | Institution       |                               |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 4 / 5,0                                                                                                                                      | Module owner      | Prof. Dr. Guillermo Payá Vayá |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 150                                                                                                                                          |                   |                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 56                                                                                                                                           | Self studying (h) | 94                            |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                              |                   |                               |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | The courses “Hardware-Software-Systems”, “Digital Circuits Design”, and “Hardware Praktikum” are recommended as preparation for this course. |                   |                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1 graded work: Written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam                                                         |                   |                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                              |                   |                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                              |                   |                               |
| 1. Introduction to Reconfigurable Computing<br>2. FPGA Basic Architecture (incl. DSP blocks, embedded memories, soft and hard processors) (Review)<br>3. Additional Architectural Elements of FPGAs (Boundary scan, I/O cells (PLLs), MIG, transceivers, analog-to-digital converters, ...)<br>4. FPGA Memory Technologies (SRAM, EPROM, Flash, Anti-Fuse, MRAM)<br>5. High-Performance Circuit Design on FPGAs<br>6. Dynamic and Partial Reconfiguration Mechanisms (incl. Space-Time FPGAs)<br>7. Design Tools for FPGAs (incl. VTR)<br>8. FPGA-Based Applications                                                                  |                                                                                                                                              |                   |                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                              |                   |                               |
| After completing the module, the students know how to design and optimize complex circuits on modern FPGA devices. Moreover, they are capable to efficiently use all the embedded dedicated hardware modules, e.g., DSPs, different embedded memories, I/O high speed interfaces, or analog-to-digital converters. This course makes emphasis on the design of high performance circuits by understanding the FPGA architecture limitations and including dynamic and partial reconfiguration mechanisms. The students will be introduced to emerging reconfigurable logic devices and their use in demanding technical applications. |                                                                                                                                              |                   |                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                              |                   |                               |
| - Palchadhuri, A.; Chakraborty, R.S.; „High Performance Integer Arithmetic Circuit Design on FPGA“, Springer, 2016<br><br>- Deschamps, J-P.; Sutter, G.D.; Cantó, E. : „Guide to FPGA Implementation of Arithmetic Functions“, Springer, 2012<br><br>- Rodriguez-Andina, J.J.; et. al.: „FPGAs. Fundamentals, Advanced Features, and Applications in Industrial Electronics“, CRC Press, 2017<br><br>- Ashenden, P.: "The Designers Guide to VHDL", Morgan Kaufmann, 3rd revised edition, November 2006                                                                                                                               |                                                                                                                                              |                   |                               |

- Bergeron, J.: "Writing Testbenches: Functional Verification of HDL Models", Springer-Verlag, 2003
- Betz, V.; Rose, J.; Marquardt, A.: "Architecture and CAD for Deep-Submicron FPGAs", Kluwer, 1999
- Bobda, C.: "Introduction to Reconfigurable Computing", Springer-Verlag, 2007
- Grout, I.: "Digital System Design with FPGAs and CPLDs", Elsevier Science & Technology, 2008
- Hunter, R.; Johnson, T.: "VHDL", Springer-Verlag, 2007
- Meyer-Baese, U.: "Digital Signal Processing with Field Programmable Gate Arrays", Springer-Verlag, 2007
- Rahman, A.: "FPGA based Design and applications", Springer-Verlag, 2008
- Sikora, A.: "Programmierbare Logikbauelemente", Hanser-Verlag, 2001
- Wilson, P.: "Design Recipes for FPGAs", Elsevier Science & Technology, 2007

Further references will be announced in the course



| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |     |                  |                |
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| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |     |                  |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |                  |                |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |                  |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |                  |                |
| Name of the course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | SWS | Eventtype        | Language       |
| Advanced FPGA-Design                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 4,0 | Lecture/Exercise | english german |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |                  |                |
| <p>- Palchaudhuri, A.; Chakraborty, R.S.; „High Performance Integer Arithmetic Circuit Design on FPGA“, Springer, 2016 - Deschamps, J-P.; Sutter, G.D.; Cantó, E. : „Guide to FPGA Implementation of Arithmetic Functions“, Springer, 2012 - Rodriguez-Andina, J.J.; et. al.: „FPGAs. Fundamentals, Advanced Features, and Applications in Industrial Electronics“, CRC Press, 2017 - Ashenden, P.: "The Designers Guide to VHDL", Morgan Kaufmann, 3rd revised edition, November 2006 - Bergeron, J.: "Writing Testbenches: Functional Verification of HDL Models", Springer-Verlag, 2003 - Betz, V.; Rose, J.; Marquardt, A.: "Architecture and CAD for Deep-Submicron FPGAs", Kluwer, 1999 - Bobda, C.: "Introduction to Reconfigurable Computing", Springer-Verlag, 2007 - Grout, I.: "Digital System Design with FPGAs and CPLDs", Elsevier Science &amp; Technology, 2008 - Hunter, R.; Johnson, T.: "VHDL", Springer-Verlag, 2007 - Meyer-Baese, U.: "Digital Signal Processing with Field Programmable Gate Arrays", Springer-Verlag, 2007 - Rahman, A.: "FPGA based Design and applications", Springer-Verlag, 2008 - Sikora, A.: "Programmierbare Logikbauelemente", Hanser-Verlag, 2001 - Wilson, P.: "Design Recipes for FPGAs", Elsevier Science &amp; Technology, 2007 (EN) Further references will be announced in the course</p> |     |                  |                |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                            |                   |                                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|--------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Human-Robot Interaction                                                                                                                                    |                   |                                |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 4215000020                                                                                                                                                 | Module version    |                                |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                            | Language          | english german                 |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | only in the summer term                                                                                                                                    | Teaching unit     | Carl-Friedrich-Gauß-Fakultät   |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1                                                                                                                                                          | Institution       | Institut für Kognitive Robotik |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 4 / 5,0                                                                                                                                                    | Module owner      | Prof. Dr. Jens Lambrecht       |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 150                                                                                                                                                        |                   |                                |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 56                                                                                                                                                         | Self studying (h) | 94                             |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                            |                   |                                |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | The course assumes basic knowledge in mathematics and statistics as acquired in the introductory course in mathematics in the computer science curriculum. |                   |                                |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Written exam (90 minutes) or oral exam (30 min)                                                                                                            |                   |                                |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                            |                   |                                |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                            |                   |                                |
| <p>This module covers fundamental concepts, methods, and applications of human-robot interaction. Topics include:</p> <ul style="list-style-type: none"><li>• Fundamentals and definitions of human-robot interaction</li><li>• Application fields: industrial, service, healthcare, and social robotics</li><li>• Safety in collaborative robotic systems and relevant standards (ISO 10218, ISO/TS 15066)</li><li>• Physical interaction: haptic feedback, force and impedance control</li><li>• Social robots: non-verbal communication, gestures, and facial expressions</li><li>• Speech-based and multimodal interaction</li><li>• User-centered design and usability evaluation</li><li>• Trust, acceptance, and situational awareness</li><li>• Ethical, legal, and societal aspects of HRI</li><li>• Current research directions and application scenarios</li></ul>                                                                                                                                                                                                                                                                                               |                                                                                                                                                            |                   |                                |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                            |                   |                                |
| <p>Upon successful completion of this module, students will have foundational knowledge of the design, evaluation, and safe implementation of human-robot interaction systems. Students will be able to develop interaction concepts for real-world application scenarios and evaluate them with respect to technical, ergonomic, and ethical criteria.</p> <p>They are able to</p> <ul style="list-style-type: none"><li>• Identify and classify fundamental concepts, paradigms, and application fields of human-robot interaction</li><li>• Explain and apply safety requirements and relevant standards (including ISO 10218, ISO/TS 15066) for collaborative robotic systems</li><li>• Describe and compare methods of physical and social interaction between humans and robots</li><li>• Design user-centered interfaces and interaction concepts and evaluate them with respect to usability</li><li>• Analyze factors such as trust, acceptance, and situational awareness in HRI systems and incorporate them into system development</li><li>• Reflect on and evaluate the ethical and societal implications of deploying robots in human environments</li></ul> |                                                                                                                                                            |                   |                                |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                            |                   |                                |

- Christoph Bartneck et al.: Human-Robot Interaction: An Introduction
- Breazeal, Dautenhahn & Forlizzi: Social Robots that Interact with People
- Goodrich & Schultz: Human-Robot Interaction: A Survey
- slides, further references will be announced in the course



| Related courses                 |     |                  |                |
|---------------------------------|-----|------------------|----------------|
| Rules for the choice of courses |     |                  |                |
|                                 |     |                  |                |
| Compulsory attendance           |     |                  |                |
|                                 |     |                  |                |
| Name of the course              | SWS | Eventtype        | Language       |
| Human-Robot Interaction         | 4,0 | Lecture/Exercise | english german |

**Major Specialisation: Microelectronics Engineering - Compulsory Elective Modules**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Analog Integrated Circuits |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2420150                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                          | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                    | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                         | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam 30 min           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                   |                                                          |
| <p>All modern mobile radio applications (e.g. GSM, WLAN, GPS, Bluetooth, Dect. etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are increasingly being integrated in low-cost CMOS technology, which results in significant differences to the classic design of high-frequency circuits based on discrete components. The lecture gives an introduction to the design of analog, integrated CMOS mobile radio receiver circuits.</p> <p>The lecture is divided into the following chapters:</p> <ul style="list-style-type: none"><li>- High frequency amplifier circuits</li><li>- Simulation of electronic noise</li><li>- Low-noise input amplifiers in CMOS</li><li>- Mixer circuits</li><li>- Phase-locked loops (PLLs)</li><li>- Voltage-controlled oscillators</li></ul> |                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| <p>After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                   |                                                          |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits" Cambridge University Press                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |



| <b>Related courses</b>                            |            |                  |                 |
|---------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>            |            |                  |                 |
| Prerequisite for this module: Circuit Design (ST) |            |                  |                 |
| <b>Compulsory attendance</b>                      |            |                  |                 |
|                                                   |            |                  |                 |
| <b>Name of the course</b>                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Analog Integrated Circuits (2013)                 | 1,0        | Exercise         | english         |
| Analog Integrated Circuits (2013)                 | 2,0        | Lecture          | english         |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Advanced Analog Integrated Circuits         |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2420000060                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                           | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                     | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | oral exam (30 min) or written exam (90 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                             |                   |                                                          |
| All modern mobile communications applications (e.g. 5G, 6G, etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are integrated into the inexpensive CMOS technology, which results in significant differences to the classic design of high-frequency circuits based on discrete components. The lecture provides an introduction to the design of analog, integrated CMOS mobile radio receiver circuits. The lecture is divided into the following chapters: • High-frequency amplifier circuits • Electronic noise • Low-noise amplifiers in CMOS • Mixer circuits • Voltage-controlled oscillators • Power amplifiers                                                                                                                                                                    |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| After completing the module, students will have acquired knowledge of analog receive and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for cellular applications (e.g. radio frequency amplifier circuits, electronic noise simulation). You have a basic knowledge of using the Specter-RF design tool, which is widely used in the industry for analog integrated circuit design. In accordance with the didactic concept of the event and the design of the individual components, interdisciplinary qualifications are taught or practiced. In the context of elaborations, colloquia and final presentations, these include scientific writing and documentation, conversation management and presentation techniques as well as teamwork in the laboratory or project. |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |

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|                                                                                                     |            |                  |                 |
|-----------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                              |            |                  |                 |
|                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                        |            |                  |                 |
|                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Advanced Analog Integrated Circuits                                                                 | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                   |            |                  |                 |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press |            |                  |                 |
| Advanced Analog Integrated Circuits                                                                 | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                   |            |                  |                 |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press |            |                  |                 |

| Title                                        | Materials and Device Analysis               |                   |                                                          |
|----------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                       | 2413000050                                  | Module version    |                                                          |
| Shorttext                                    |                                             | Language          | english                                                  |
| Frequency of offer                           | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                              | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                        | 3 / 5,0                                     | Module owner      | Prof. Dr. Tobias Voß                                     |
| Workload (h)                                 | 150                                         |                   |                                                          |
| Class attendance (h)                         | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                      |                                             |                   |                                                          |
| Expected performance/<br>Type of examination | written exam (30 min) or oral exam (60 min) |                   |                                                          |
| Course achievement                           |                                             |                   |                                                          |

#### Contents

With a focus on optical and electrical characterisation methods, procedures for the investigation of materials and devices from the field of semiconductor technology are presented:

1. optical spectroscopy and microscopy methods
  1. absorption spectroscopy
  2. fluorescence spectroscopy
  3. time-resolved spectroscopy
  4. IR spectroscopy
  5. Raman spectroscopy and microscopy
  6. photon correlation spectroscopy
2. scanning electron microscopy
3. x-ray diffraction
4. atomic force microscopy
5. electrical measurement techniques
  1. IV
  2. CV
  3. hall effect measurements
  4. Electrical measurement methods in the atomic force microscope

The methods are each explained on the basis of application fields with typical material systems, whereby silicon, III-V/II-VI semiconductors, group III nitrides and common substrate materials (SiC, sapphire) are discussed.

#### Objective qualification

Students are familiar with important optical, electrical and other characterisation methods used in the field of semiconductor technology. They will be able to select suitable methods for specific materials and components and explain and evaluate the information that can be obtained in each case. They will be able to describe the fundamental processes in the material in the respective measurement methods using technical terminology and will be able to plot, analyse and discuss individual measurement results provided.

#### Literature



#### Related courses

#### Rules for the choice of courses

#### Compulsory attendance

#### Name of the course

#### SWS

#### Eventtype

#### Language

Materials and Device Analysis

2,0

Lecture

english

Materials and Device Analysis

1,0

Exercise

english

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                             |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Advanced Network Analysis                   |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2420000050                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1                                           | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 3 / 5,0                                     | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>• Review of the Laplace transform</li><li>• Review of Kirchhoff's laws</li><li>• Review of modified nodal analysis</li><li>• Properties and analysis of N-port networks</li><li>• Tellegen's theorem and its applications in network theory</li><li>• Foster networks and synthesis methods</li><li>• Fundamentals of graph theory for electrical networks</li><li>• Bloch-Floquet theorem for the analysis of periodic structures</li><li>• Periodicity in electrical networks and its implications</li><li>• Introduction to metamaterials and their modelling</li></ul>   |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             |                   |                                                          |
| Upon completion of the module, students will have a solid overview of advanced methods for analyzing electrical networks. They will possess in-depth knowledge of the mathematical description and modeling of complex networks using the Laplace transform, Kirchhoff's laws, and Modified Nodal Analysis (MNA). Students will be familiar with key concepts such as Tellegen's theorem, Foster synthesis, periodic structures, and fundamental network synthesis methods. They will be able to select and apply appropriate analysis techniques and systematically evaluate networks in terms of their behavior. |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| Pozar, D. M. (2011). Microwave Engineering (4th ed.). Wiley                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |



|                                                              |            |                  |                 |
|--------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                       |            |                  |                 |
| <b>Rules for the choice of courses</b>                       |            |                  |                 |
|                                                              |            |                  |                 |
| <b>Compulsory attendance</b>                                 |            |                  |                 |
|                                                              |            |                  |                 |
| <b>Name of the course</b>                                    | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Advanced Network Analysis                                    | 2,0        | Lecture          | english         |
| <b>Literature</b>                                            |            |                  |                 |
| Pozar, D. M. (2011). Microwave Engineering (4th ed.). Wiley. |            |                  |                 |
| Advanced Network Analysis                                    | 1,0        | Exercise         | english         |
| <b>Literature</b>                                            |            |                  |                 |
| Pozar, D. M. (2011). Microwave Engineering (4th ed.). Wiley. |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Gallium Nitride Technology                  |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2413000030                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                     | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| <p>The course builds on 'Lighting Technology I'. While Lighting Technology I focusses on general questions of lighting and lighting technology, this course discusses LED technology and gallium nitride technology in particular:</p> <ul style="list-style-type: none"><li>• Physical principles of LEDs. Band gap engineering in LEDs.</li><li>• Semiconductor materials for optoelectronics</li><li>• Relationship between material properties and LED properties</li><li>• Manufacturing processes</li><li>• Efficiency considerations</li><li>• Front-end and back-end processing</li><li>• Application examples in general lighting, automotive technology, sensor technology</li><li>• Infrared LEDs, visible light, UV LEDs</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| After completing the module, students will have an overview of the current state of LED technology and the development opportunities that solid state lighting will offer in the future. In addition, they will have a basic understanding of the physical processes within LEDs.                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Gallium Nitride Technology             | 2,0        | Lecture          | german          |
| Gallium Nitride Technology             | 1,0        | Exercise         | german          |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Semiconductor Technology |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2413420                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                          | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the summer term  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                        | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                  | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                       | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                          |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Oral exam 30 min         |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                          |                   |                                                          |
| <ul style="list-style-type: none"><li>- physical and chemical basics</li><li>- manufacturing of single crystals and wafers</li><li>- epitaxial crystal growth processes and crystal defects</li><li>- doping processes</li><li>- semiconductor measurement technology</li><li>- planar technology</li><li>- basics of photolithography, deposition processes for dielectrics and etching processes</li></ul>                                                                                                                                                                               |                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                          |                   |                                                          |
| After completing the semiconductor technology module, students have: <ul style="list-style-type: none"><li>• an understanding of the basic manufacturing technologies of semiconductors as well as components and integrated circuits made from them.</li><li>• the ability to recognize the principles of the most modern manufacturing processes in semiconductor technology and their modes of operation</li><li>• the ability to analyze and extrapolate trends in semiconductor technology developments</li></ul>                                                                     |                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                          |                   |                                                          |
| <ul style="list-style-type: none"><li>• Lecture transparencies</li><li>• Script in Englisch (H.-H. Wehmann and A. Schlachetzki)</li><li>• Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(Stuttgart, 1998) ISBN: 3-519-06167-8</li><li>• Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (Berlin, 1991) ISBN: 3-540-53873-9</li><li>• Werner Prost: Technologie der III/V-Halbleiter, Springer (Berlin, 1997) ISBN. 3-540-62804-5</li><li>• Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (Stuttgart, 2004) ISBN: 3-519-30149-0</li></ul> |                          |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                          |                   |                                                          |
| Language German or English                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                          |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Semiconductor Technology                                                                                                                                                                                                                                                                                                                          | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner (1998)<br>Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (1991)<br>Werner Prost: Technologie der III/V-Halbleiter, Springer (1997)<br>Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (2004)<br>Ausführliches Skript in Englisch Vorlesungsfolien |            |                  |                 |
| Semiconductor Technology                                                                                                                                                                                                                                                                                                                          | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| Übungsmaterial wird verteilt.                                                                                                                                                                                                                                                                                                                     |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Integrated Circuits for Biomedical Applications |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2420190                                         | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                 | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the winter term                         | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                               | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                         | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                             |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                                              | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                 |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam (30 min) or written exam (90 min)     |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                 |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                 |                   |                                                          |
| <ul style="list-style-type: none"><li>- Introduction to biomedical applications</li><li>- Biosensing principles (physical, electrical and electrochemical)</li><li>- Basic biomedical circuits: transimpedance and instrumentation amplifiers, oscillators, ADCs/DACs</li><li>- Basic circuits for Power Management (DCDC, LDO, Rectifier)</li><li>- Self-powering and energy storage (e.g. biofuel cell sensing, energy harvesting)</li><li>- Wireless Power Transfer (WPT) for implantable devices</li><li>- Circuits for ultra-low power data transmission</li><li>- Circuits for electrochemical sensing (potentiometric and amperometric)</li><li>- Examples of potentiometric biosensors (pH, K+, Na+, Ca+ etc) and iontophoresis</li><li>- Circuits for Impedance Spectroscopy</li><li>- Radar-based Imaging for Breast Cancer Detection</li><li>- Circuits for Electrical Impedance Tomography</li><li>- Resonance-based dielectric sensors (e.g. for glucose detection)</li><li>- Circuits for cochlear implants</li></ul> |                                                 |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                 |                   |                                                          |
| Upon completion of this module, the students will acquire knowledge about integrated circuits for various biomedical applications and obtain a deep understanding about circuit techniques for design of analog integrated circuits for biomedical applications (e.g. HF-oscillators for glucose sensing).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |
| “Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems”, Rahul Sarpeshkar, Cambridge University Press, 2010<br>“Power Management Integrated Circuits (Devices, Circuits, and Systems)”, M. Hella, P. Mercier, CRC Press, 2016<br>“Introduction to Biosensors From Electric Circuits to Immunosensors”, J.-Y. Yoon, Springer 2016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                            | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
| Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems, Rahul Sarpeshkar, Cambridge University Press, 2010<br>Power Management Integrated Circuits (Devices, Circuits, and Systems), M. Hella, P. Mercier, CRC Press, 2016<br>Introduction to Biosensors From Electric Circuits to Immunosensors, J.-Y. Yoon, Springer 2016 |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Exercise         | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
| Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems, Rahul Sarpeshkar, Cambridge University Press, 2010<br>Power Management Integrated Circuits (Devices, Circuits, and Systems), M. Hella, P. Mercier, CRC Press, 2016<br>Introduction to Biosensors From Electric Circuits to Immunosensors, J.-Y. Yoon, Springer 2016 |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                             | Sensor Technology                                                                                                                                             |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                            | 2413000040                                                                                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                         |                                                                                                                                                               | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                | only in the summer term                                                                                                                                       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                   | 1                                                                                                                                                             | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                             | 3 / 5,0                                                                                                                                                       | Module owner      |                                                          |
| Workload (h)                                                                                                                                                                                                                                                                                      | 150                                                                                                                                                           |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                              | 42                                                                                                                                                            | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                           |                                                                                                                                                               |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                                          | Attending Materials & Device Analysis; Fundamentals of NanoOptics; Integrated Circuits for Biomedical Applications in addition to the lecture is recommended. |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                         | Written exam (60 min) or oral exam (30 min)                                                                                                                   |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                | Project work (design project), either with written assignment or final presentation/colloquium                                                                |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                          |                                                                                                                                                               |                   |                                                          |
|                                                                                                                                                                                                                                                                                                   |                                                                                                                                                               |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                           |                                                                                                                                                               |                   |                                                          |
|                                                                                                                                                                                                                                                                                                   |                                                                                                                                                               |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                        |                                                                                                                                                               |                   |                                                          |
| Core Texts: <ul style="list-style-type: none"><li>• Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010</li><li>• Horowitz &amp; Hill: The Art of Electronics (2nd ed), CUP, 1989</li></ul>                                                                                           |                                                                                                                                                               |                   |                                                          |
| Supplementary: <ul style="list-style-type: none"><li>• Pallás-Areny &amp; Webster: Analog Signal Processing, Wiley, 1999</li><li>• MIT OCW readings &amp; lecture notes from MAS#836 Sensor Technologies</li><li>• Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)</li></ul> |                                                                                                                                                               |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Sensor Technology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <p>Core Texts:</p> <ul style="list-style-type: none"> <li>• Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010</li> <li>• Horowitz &amp; Hill: The Art of Electronics (2nd ed), CUP, 1989</li> </ul> <p>Supplementary:</p> <ul style="list-style-type: none"> <li>• Pallás-Areny &amp; Webster: Analog Signal Processing, Wiley, 1999</li> <li>• MIT OCW readings &amp; lecture notes from MAS#836 Sensor Technologies</li> <li>• Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)</li> </ul> |            |                  |                 |
| Sensor Technology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| Project and sensor type-specific; s. lecture for literature and provided articles.                                                                                                                                                                                                                                                                                                                                                                                                                                             |            |                  |                 |

**Major Specialisation: Microelectronics Engineering - Elective Modules**

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                              |                   |                               |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4211510                                                                                                                                      | Module version    |                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                              | Language          | english                       |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | only in the summer term                                                                                                                      | Teaching unit     | Carl-Friedrich-Gauß-Fakultät  |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1 Semester                                                                                                                                   | Institution       |                               |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 4 / 5,0                                                                                                                                      | Module owner      | Prof. Dr. Guillermo Payá Vayá |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 150                                                                                                                                          |                   |                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 56                                                                                                                                           | Self studying (h) | 94                            |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                              |                   |                               |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | The courses “Hardware-Software-Systems”, “Digital Circuits Design”, and “Hardware Praktikum” are recommended as preparation for this course. |                   |                               |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1 graded work: Written exam (90 minutes) or oral exam (30 minutes)                                                                           |                   |                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                              |                   |                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                              |                   |                               |
| 1. Introduction to Reconfigurable Computing<br>2. FPGA Basic Architecture (incl. DSP blocks, embedded memories, soft and hard processors) (Review)<br>3. Additional Architectural Elements of FPGAs (Boundary scan, I/O cells (PLLs), MIG, transceivers, analog-to-digital converters, ...)<br>4. FPGA Memory Technologies (SRAM, EPROM, Flash, Anti-Fuse, MRAM)<br>5. High-Performance Circuit Design on FPGAs<br>6. Dynamic and Partial Reconfiguration Mechanisms (incl. Space-Time FPGAs)<br>7. Design Tools for FPGAs (incl. VTR)<br>8. FPGA-Based Applications                                                                  |                                                                                                                                              |                   |                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                              |                   |                               |
| After completing the module, the students know how to design and optimize complex circuits on modern FPGA devices. Moreover, they are capable to efficiently use all the embedded dedicated hardware modules, e.g., DSPs, different embedded memories, I/O high speed interfaces, or analog-to-digital converters. This course makes emphasis on the design of high performance circuits by understanding the FPGA architecture limitations and including dynamic and partial reconfiguration mechanisms. The students will be introduced to emerging reconfigurable logic devices and their use in demanding technical applications. |                                                                                                                                              |                   |                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                              |                   |                               |
| - Palchaudhuri, A.; Chakraborty, R.S.; „High Performance Integer Arithmetic Circuit Design on FPGA“, Springer, 2016<br><br>- Deschamps, J-P.; Sutter, G.D.; Cantó, E. : „Guide to FPGA Implementation of Arithmetic Functions“, Springer, 2012<br><br>- Rodriguez-Andina, J.J.; et. al.: „FPGAs. Fundamentals, Advanced Features, and Applications in Industrial Electronics“. CRC Press. 2017                                                                                                                                                                                                                                        |                                                                                                                                              |                   |                               |

- Ashenden, P.: "The Designers Guide to VHDL", Morgan Kaufmann, 3rd revised edition, November 2006
- Bergeron, J.: "Writing Testbenches: Functional Verification of HDL Models", Springer-Verlag, 2003
- Betz, V.; Rose, J.; Marquardt, A.: "Architecture and CAD for Deep-Submicron FPGAs", Kluwer, 1999
- Bobda, C.: "Introduction to Reconfigurable Computing", Springer-Verlag, 2007
- Grout, I.: "Digital System Design with FPGAs and CPLDs", Elsevier Science & Technology, 2008
- Hunter, R.; Johnson, T.: "VHDL", Springer-Verlag, 2007
- Meyer-Baese, U.: "Digital Signal Processing with Field Programmable Gate Arrays", Springer-Verlag, 2007
- Rahman, A.: "FPGA based Design and applications", Springer-Verlag, 2008
- Sikora, A.: "Programmierbare Logikbauelemente", Hanser-Verlag, 2001
- Wilson, P.: "Design Recipes for FPGAs", Elsevier Science & Technology, 2007

Further references will be announced in the course



| Related courses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |                  |                |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------------|----------------|
| Rules for the choice of courses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |                  |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |                  |                |
| Compulsory attendance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |     |                  |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |                  |                |
| Name of the course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | SWS | Eventtype        | Language       |
| Advanced FPGA-Design                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 4,0 | Lecture/Exercise | english german |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |     |                  |                |
| - Palchaudhuri, A.; Chakraborty, R.S.; „High Performance Integer Arithmetic Circuit Design on FPGA“, Springer, 2016 - Deschamps, J-P.; Sutter, G.D.; Cantó, E.: „Guide to FPGA Implementation of Arithmetic Functions“, Springer, 2012 - Rodriguez-Andina, J.J.; et. al.: „FPGAs. Fundamentals, Advanced Features, and Applications in Industrial Electronics“, CRC Press, 2017 - Ashenden, P.: "The Designers Guide to VHDL", Morgan Kaufmann, 3rd revised edition, November 2006 - Bergeron, J.: "Writing Testbenches: Functional Verification of HDL Models", Springer-Verlag, 2003 - Betz, V.; Rose, J.; Marquardt, A.: "Architecture and CAD for Deep-Submicron FPGAs", Kluwer, 1999 - Bobda, C.: "Introduction to Reconfigurable Computing", Springer-Verlag, 2007 - Grout, I.: "Digital System Design with FPGAs and CPLDs", Elsevier Science & Technology, 2008 - Hunter, R.; Johnson, T.: "VHDL", Springer-Verlag, 2007 - Meyer-Baese, U.: "Digital Signal Processing with Field Programmable Gate Arrays", Springer-Verlag, 2007 - Rahman, A.: "FPGA based Design and applications", Springer-Verlag, 2008 - Sikora, A.: "Programmierbare Logikbauelemente", Hanser-Verlag, 2001 - Wilson, P.: "Design Recipes for FPGAs", Elsevier Science & Technology, 2007 (EN) Further references will be announced in the course |     |                  |                |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Advanced Analog Integrated Circuits         |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2420000060                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                           | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                     | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | oral exam (30 min) or written exam (90 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                             |                   |                                                          |
| All modern mobile communications applications (e.g. 5G, 6G, etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are integrated into the inexpensive CMOS technology, which results in significant differences to the classic design of high-frequency circuits based on discrete components. The lecture provides an introduction to the design of analog, integrated CMOS mobile radio receiver circuits. The lecture is divided into the following chapters: • High-frequency amplifier circuits • Electronic noise • Low-noise amplifiers in CMOS • Mixer circuits • Voltage-controlled oscillators • Power amplifiers                                                                                                                                                                    |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| After completing the module, students will have acquired knowledge of analog receive and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for cellular applications (e.g. radio frequency amplifier circuits, electronic noise simulation). You have a basic knowledge of using the Specter-RF design tool, which is widely used in the industry for analog integrated circuit design. In accordance with the didactic concept of the event and the design of the individual components, interdisciplinary qualifications are taught or practiced. In the context of elaborations, colloquia and final presentations, these include scientific writing and documentation, conversation management and presentation techniques as well as teamwork in the laboratory or project. |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |

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|-----------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                              |            |                  |                 |
|                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                        |            |                  |                 |
|                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Advanced Analog Integrated Circuits                                                                 | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                   |            |                  |                 |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press |            |                  |                 |
| Advanced Analog Integrated Circuits                                                                 | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                   |            |                  |                 |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press |            |                  |                 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Analog Integrated Circuits |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2420150                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                            | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                          | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 4 / 5,0                    | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 56                         | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam 30 min           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                   |                                                          |
| <p>All modern mobile radio applications (e.g. GSM, WLAN, GPS, Bluetooth, Dect. etc.) use analog receiver and transmitter circuits that are composed of a few elementary circuit blocks. For cost reasons, these are increasingly being integrated in low-cost CMOS technology, which results in significant differences to the classic design of high-frequency circuits based on discrete components. The lecture gives an introduction to the design of analog, integrated CMOS mobile radio receiver circuits.</p> <p>The lecture is divided into the following chapters:</p> <ul style="list-style-type: none"><li>- High frequency amplifier circuits</li><li>- Simulation of electronic noise</li><li>- Low-noise input amplifiers in CMOS</li><li>- Mixer circuits</li><li>- Phase-locked loops (PLLs)</li><li>- Voltage-controlled oscillators</li></ul> |                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                            |                   |                                                          |
| <p>After completing the module, students will have acquired knowledge of analog receiver and transmitter circuits in CMOS technology and have an advanced understanding of the design and function of modern analog integrated circuits for mobile radio applications (e.g. high-frequency amplifier circuits and simulation of electronic noise).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                            |                   |                                                          |
| Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits" Cambridge University Press                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                            |                   |                                                          |

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| <b>Related courses</b>                            |            |                  |                 |
|---------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>            |            |                  |                 |
| Prerequisite for this module: Circuit Design (ST) |            |                  |                 |
| <b>Compulsory attendance</b>                      |            |                  |                 |
|                                                   |            |                  |                 |
| <b>Name of the course</b>                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Analog Integrated Circuits (2013)                 | 1,0        | Exercise         | english         |
| Analog Integrated Circuits (2013)                 | 2,0        | Lecture          | english         |

| Title                                        | Materials and Device Analysis               |                   |                                                          |
|----------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                       | 2413000050                                  | Module version    |                                                          |
| Shorttext                                    |                                             | Language          | english                                                  |
| Frequency of offer                           | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                              | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                        | 3 / 5,0                                     | Module owner      | Prof. Dr. Tobias Voß                                     |
| Workload (h)                                 | 150                                         |                   |                                                          |
| Class attendance (h)                         | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                      |                                             |                   |                                                          |
| Expected performance/<br>Type of examination | written exam (30 min) or oral exam (60 min) |                   |                                                          |
| Course achievement                           |                                             |                   |                                                          |

#### Contents

With a focus on optical and electrical characterisation methods, procedures for the investigation of materials and devices from the field of semiconductor technology are presented:

1. optical spectroscopy and microscopy methods
  1. absorption spectroscopy
  2. fluorescence spectroscopy
  3. time-resolved spectroscopy
  4. IR spectroscopy
  5. Raman spectroscopy and microscopy
  6. photon correlation spectroscopy
2. scanning electron microscopy
3. x-ray diffraction
4. atomic force microscopy
5. electrical measurement techniques
  1. IV
  2. CV
  3. hall effect measurements
  4. Electrical measurement methods in the atomic force microscope

The methods are each explained on the basis of application fields with typical material systems, whereby silicon, III-V/II-VI semiconductors, group III nitrides and common substrate materials (SiC, sapphire) are discussed.

#### Objective qualification

Students are familiar with important optical, electrical and other characterisation methods used in the field of semiconductor technology. They will be able to select suitable methods for specific materials and components and explain and evaluate the information that can be obtained in each case. They will be able to describe the fundamental processes in the material in the respective measurement methods using technical terminology and will be able to plot, analyse and discuss individual measurement results provided.

#### Literature



#### Related courses

##### Rules for the choice of courses

##### Compulsory attendance

| Name of the course            | SWS | Eventtype | Language |
|-------------------------------|-----|-----------|----------|
| Materials and Device Analysis | 2,0 | Lecture   | english  |
| Materials and Device Analysis | 1,0 | Exercise  | english  |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                              |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Applied Power Electronics                    |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2414230                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                              | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                            | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                      | Module owner      | Prof. Dr. Regine Mallwitz                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                                           | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                              |                   |                                                          |
| <ul style="list-style-type: none"><li>• Power electronics and electromagnetic compatibility (EMC)</li><li>• EMC guidelines and filter circuits</li><li>• Power Factor Correction (PFC)</li><li>• Resonant power converters</li><li>• Quasi-resonant circuits</li><li>• Multi-level converters</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                              |                   |                                                          |
| After completing the module, students will acquire knowledge of legal requirements regarding electromagnetic compatibility. They will learn the structure, function, application and design of passive and active filter circuits. An important aspect here is to obtain a mains current that is as sinusoidal as possible in phase with the mains voltage with the help of so-called power factor correction (PFC). Students should understand how resonant power converters and quasi-resonant circuits work and how they are used, also by means of simulations. Finally, they should be able to understand the structure and function of multi-level converters. They will be able to conceptually design, dimension and analyse (also by simulation) corresponding assemblies. |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                   |                                                          |
| Grundkurs Leistungselektronik, Joachim Specovius, Vieweg-Verlag<br>Applikationshandbuch Leistungshalbleiter, Semikron, ISLE-Verlag                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |

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| <b>Related courses</b>                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                 | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                               |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Skript</li> <li>- DIN 41750: "Begriffe für Stromrichter", Beuth Verlag GmbH, 1984</li> <li>- Jötten, R.: "Leistungselektronik", Vieweg Verlag, Braunschweig, 1977</li> <li>- Heumann/Stumpe: "Thyristoren", Teubner Verlag, Stuttgart, 1970</li> </ul> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                 | 2,0        | Exercise         | german          |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                            |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Applied Quantum Computing: Basics and Devices                                              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2413620                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                            | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the winter term                                                                    | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                                                                                          | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3 / 5,0                                                                                    | Module owner      | Prof. Dr. Stefanie Kroker                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                                                                                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                                                                                         | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                            |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (120 min) or oral exam (30 min), alternativ: homework with final presentation |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                            |                   |                                                          |
| <ul style="list-style-type: none"><li>- Basics of Quantum Mechanics</li><li>- From Bit to Qubit</li><li>- Quantum Circuits I</li><li>- Quantum Circuits II</li><li>- Entanglement and Teleportation</li><li>- Algorithms of Quantum Computing</li><li>- Quantum Hardware I</li><li>- Quantum Hardware II</li></ul>                                                                                                                                                                                                                                                                                                                                                              |                                                                                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                            |                   |                                                          |
| <ul style="list-style-type: none"><li>- The students can name the prerequisites for the realization of qubits as well as typical platforms and explain their significance.</li><li>- Students will be able to name the strengths and weaknesses of different hardware platforms in common application scenarios and weigh them against each other.</li><li>- The students can name the essential process steps for the realization of different quantum computer platforms and to explain challenges that may arise in the manufacturing process.</li><li>- Students will be able to use an exemplary platform to explain how selected quantum gates can be realized.</li></ul> |                                                                                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                            |                   |                                                          |
| <p>[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019<br/>[2] M. A. Nielsen &amp; I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010<br/>[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019<br/>[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018<br/>[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019</p>                                                                                                                                                                                                                                                  |                                                                                            |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                       | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Applied Quantum Computing: Basics and Devices                                                                                                                                                                                                                                                                                                                                                                   | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| [1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019<br>[2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010<br>[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019<br>[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018<br>[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019 |            |                  |                 |
| Applied Quantum Computing: Basics and Devices                                                                                                                                                                                                                                                                                                                                                                   | 1,0        | Exercise         | german          |

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|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Packaging and Interconnection Technology |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2413390                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                          | Language          | german                                                   |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | only in the summer term                  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1                                        | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 3 / 5,0                                  | Module owner      | Prof. Dr. Erwin Peiner                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 150                                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 42                                       | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                          |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | oral exam (30 min)                       |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                          |                   |                                                          |
| <ul style="list-style-type: none"><li>- Open wiring, bread board, printed circuit board</li><li>- Thick film technologies, substrates, screen printing and pastes, thin film technology, photolithography</li><li>- Surface mount technology, components, housing forms, modern developments (TAB, BGA, flip chip, CSP, MCM)</li><li>- Power modules, special requirements</li><li>- Cooling, basics and problems, air cooling, liquid cooling</li><li>- Thermomechanical stresses and reliability, basics, examples</li><li>- Soldering</li><li>- Adhesive bonding</li><li>- Wire bonding</li><li>- Direct copper bonding</li><li>- Low-temperature joining technology</li></ul> |                                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                          |                   |                                                          |
| <p>After completing the module electronic packaging, the students will have</p> <ul style="list-style-type: none"><li>- a basic understanding of the most important processes for assembling and joining electronic devices and components</li><li>- the ability to select suitable processes for packaging in the manufacture of semiconductor modules</li><li>- in-depth knowledge and practical experience in the use, analysis and evaluation of methods of electronic packaging</li></ul>                                                                                                                                                                                    |                                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                          |                   |                                                          |
| <p>W. Scheel (Hrsg.): Baugruppenteknologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) ISBN: 3-341-01100-5</p> <p>H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik # Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01097-1</p> <p>H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik # Hybridträger (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01099-8</p> <p>M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiesbaden, 1991) ISBN: 3-528-06392-0</p>                                                                                                                                     |                                          |                   |                                                          |

J. H. Lau, "Recent Advances and Trends in Advanced Packaging," in IEEE Transactions on Components, Packaging and Manufacturing Technology, vol. 12, no. 2, pp. 228-252, Feb. 2022, doi: 10.1109/TCPMT.2022.3144461.  
 Y. Yang, L. Dorn-Gomba, R. Rodriguez, C. Mak and A. Emadi, "Automotive Power Module Packaging: Current Status and Future Trends," in IEEE Access, vol. 8, pp. 160126-160144, 2020, doi: 10.1109/ACCESS.2020.3019775.  
 Morris J.E. (2018) Nanopackaging: Nanotechnologies and Electronics Packaging. In: Morris J. (eds) Nanopackaging. Springer, Cham. [https://doi.org/10.1007/978-3-319-90362-0\\_1](https://doi.org/10.1007/978-3-319-90362-0_1)



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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1,0        | Exercise         | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| Unterlagen werden verteilt.                                                                                                                                                                                                                                                                                                                                                                                                                |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2,0        | Lecture          | german          |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                  |                 |
| W. Scheel (Hrsg.): Baugruppenteknologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997)<br>H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik - Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994)<br>H.-J. Hanke (Hrsg.): Baugruppenteknologie der Elektronik - Hybridträger (Verlag Technik, Berlin, Saulgau, 1994)<br>M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiesbaden, 1991) |            |                  |                 |

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|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Introduction to Logic Circuits              |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 2420000070                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                                           | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 3 / 5,0                                     | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | oral exam (30 min) or written exam (90 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
| <div>- Introduction to CMOS</div> <div>- Basic Logic Circuits</div> <div>- Layout of digital CMOS circuits</div> <div>- Optimization and weighting of the stages</div> <div>- Delay definitions</div> <div>- Flip-Flops in standard CMOS logic</div> <div>- TSPC logic</div> <div>- C2MOS logic</div> <div>- CML logic</div> <div>- Sensitivity curves and speed optimization techniques</div>                                                                                                                                                                                                                               |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             |                   |                                                          |
| Upon completion of the module, students will have an overview of modern digital logic circuits in CMOS technology, possess system-level knowledge, and have learned methods to design and analyze digital integrated circuits independently. Students will acquire knowledge of fundamental and advanced CMOS logic families and gain an in-depth understanding of timing behavior, layout principles, and optimization of digital circuits (e.g., clocked flip-flops, TSPC, C2MOS, and CML logic). They will be able to evaluate and improve circuit designs with respect to delay, power efficiency, and area consumption. |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| - Mano, M. M., & Ciletti, M. D. (2018). Digital Design (6th ed.). Pearson. ISBN: 978-1292231167                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |

- Weste, N. H. E., & Harris, D. (2021). CMOS VLSI Design: A Circuits and Systems Perspective (4th ed.). Pearson. ISBN: 978-0136915543
- Rabaey, J. M., Chandrakasan, A., & Nikolic, B. (2003). Digital Integrated Circuits: A Design Perspective (2nd ed.). Pearson. ISBN: 978-0130909968



| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Introduction to Logic Circuits                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Mano, M. M., &amp; Ciletti, M. D. (2018). Digital Design (6th ed.). Pearson. ISBN: 978-1292231167</li> <li>- Weste, N. H. E., &amp; Harris, D. (2021). CMOS VLSI Design: A Circuits and Systems Perspective (4th ed.). Pearson. ISBN: 978-0136915543</li> <li>- Rabaey, J. M., Chandrakasan, A., &amp; Nikolic, B. (2003). Digital Integrated Circuits: A Design Perspective (2nd ed.). Pearson. ISBN: 978-0130909968</li> </ul> |            |                  |                 |
| Introduction to Logic Circuits                                                                                                                                                                                                                                                                                                                                                                                                                                            | 2,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <ul style="list-style-type: none"> <li>- Mano, M. M., &amp; Ciletti, M. D. (2018). Digital Design (6th ed.). Pearson. ISBN: 978-1292231167</li> <li>- Weste, N. H. E., &amp; Harris, D. (2021). CMOS VLSI Design: A Circuits and Systems Perspective (4th ed.). Pearson. ISBN: 978-0136915543</li> <li>- Rabaey, J. M., Chandrakasan, A., &amp; Nikolic, B. (2003). Digital Integrated Circuits: A Design Perspective (2nd ed.). Pearson. ISBN: 978-0130909968</li> </ul> |            |                  |                 |

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|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Advanced Network Analysis                   |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2420000050                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | only in the summer term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1                                           | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 3 / 5,0                                     | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| <ul style="list-style-type: none"><li>• Review of the Laplace transform</li><li>• Review of Kirchhoff's laws</li><li>• Review of modified nodal analysis</li><li>• Properties and analysis of N-port networks</li><li>• Tellegen's theorem and its applications in network theory</li><li>• Foster networks and synthesis methods</li><li>• Fundamentals of graph theory for electrical networks</li><li>• Bloch-Floquet theorem for the analysis of periodic structures</li><li>• Periodicity in electrical networks and its implications</li><li>• Introduction to metamaterials and their modelling</li></ul>   |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             |                   |                                                          |
| Upon completion of the module, students will have a solid overview of advanced methods for analyzing electrical networks. They will possess in-depth knowledge of the mathematical description and modeling of complex networks using the Laplace transform, Kirchhoff's laws, and Modified Nodal Analysis (MNA). Students will be familiar with key concepts such as Tellegen's theorem, Foster synthesis, periodic structures, and fundamental network synthesis methods. They will be able to select and apply appropriate analysis techniques and systematically evaluate networks in terms of their behavior. |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                             |                   |                                                          |
| Pozar, D. M. (2011). Microwave Engineering (4th ed.). Wiley                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |



|                                                              |            |                  |                 |
|--------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                       |            |                  |                 |
| <b>Rules for the choice of courses</b>                       |            |                  |                 |
|                                                              |            |                  |                 |
| <b>Compulsory attendance</b>                                 |            |                  |                 |
|                                                              |            |                  |                 |
| <b>Name of the course</b>                                    | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Advanced Network Analysis                                    | 2,0        | Lecture          | english         |
| <b>Literature</b>                                            |            |                  |                 |
| Pozar, D. M. (2011). Microwave Engineering (4th ed.). Wiley. |            |                  |                 |
| Advanced Network Analysis                                    | 1,0        | Exercise         | english         |
| <b>Literature</b>                                            |            |                  |                 |
| Pozar, D. M. (2011). Microwave Engineering (4th ed.). Wiley. |            |                  |                 |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Gallium Nitride Technology                  |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2413000030                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                             | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                           | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                     | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Written exam (90 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |
| <p>The course builds on 'Lighting Technology I'. While Lighting Technology I focusses on general questions of lighting and lighting technology, this course discusses LED technology and gallium nitride technology in particular:</p> <ul style="list-style-type: none"><li>• Physical principles of LEDs. Band gap engineering in LEDs.</li><li>• Semiconductor materials for optoelectronics</li><li>• Relationship between material properties and LED properties</li><li>• Manufacturing processes</li><li>• Efficiency considerations</li><li>• Front-end and back-end processing</li><li>• Application examples in general lighting, automotive technology, sensor technology</li><li>• Infrared LEDs, visible light, UV LEDs</li></ul> |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                             |                   |                                                          |
| After completing the module, students will have an overview of the current state of LED technology and the development opportunities that solid state lighting will offer in the future. In addition, they will have a basic understanding of the physical processes within LEDs.                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                             |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                             |                   |                                                          |

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|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Gallium Nitride Technology             | 2,0        | Lecture          | german          |
| Gallium Nitride Technology             | 1,0        | Exercise         | german          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Fundamentals of Nano Optics                  |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1520430                                      | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | only in the summer term                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1                                            | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 3 / 5,0                                      | Module owner      | Prof. Dr. Stefanie Kroker                                |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 150                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 42                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Written exam (120 min) or oral exam (30 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                              |                   |                                                          |
| 1. Basic concepts (photonic crystals, plasmonics)<br>2. Production and characterisation (metrology) of nano structures<br>3. Photonic nano materials / meta materials / meta surfaces<br>4. Optic nano emitters and nano antennae<br>5. Active photonic elements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                              |                   |                                                          |
| The participants can describe basic phenomena of light propagation (reflection, scattering, absorption, transmission) at interfaces and in homogeneous media qualitatively and quantitatively.<br>Participants can name important basic elements of nanooptics, such as waveguides, optical gratings, photonic crystals or metamaterials, discuss their properties qualitatively and name fields of application.<br>Participants are able to identify the basic elements in complex optical systems and describe their respective functions.<br>The participants can name important processes of micro- and nanostructuring and explain how they work.<br>The participants can solve the wave equation in simple dielectric, metallic and hybrid nanooptical systems analytically and semi-analytically and interpret the solutions.<br>Participants can classify optical resonance phenomena in nanooptical systems and name their essential properties. |                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                              |                   |                                                          |
| Novotny, Hecht: Principles of nano-optics, Cambridge University Press 2016<br>Prasad: Nanophotonics, John Wiley & Sons 2004<br>Jahns, Helfert: Introduction to Micro- and Nanooptics, Wiley VCH 2012                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                              |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Fundamentals of Nano Optics            | 2,0        | Lecture          | english         |
| Fundamentals of Nano Optics            | 1,0        | Exercise         | english         |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Semiconductor Technology |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 2413420                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                          | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | only in the summer term  | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1                        | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3 / 5,0                  | Module owner      | Prof. Dr. Andreas Waag                                   |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 150                      |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 42                       | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                          |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Oral exam 30 min         |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                          |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                          |                   |                                                          |
| <ul style="list-style-type: none"><li>- physical and chemical basics</li><li>- manufacturing of single crystals and wafers</li><li>- epitaxial crystal growth processes and crystal defects</li><li>- doping processes</li><li>- semiconductor measurement technology</li><li>- planar technology</li><li>- basics of photolithography, deposition processes for dielectrics and etching processes</li></ul>                                                                                                                                                                               |                          |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                          |                   |                                                          |
| After completing the semiconductor technology module, students have: <ul style="list-style-type: none"><li>• an understanding of the basic manufacturing technologies of semiconductors as well as components and integrated circuits made from them.</li><li>• the ability to recognize the principles of the most modern manufacturing processes in semiconductor technology and their modes of operation</li><li>• the ability to analyze and extrapolate trends in semiconductor technology developments</li></ul>                                                                     |                          |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                          |                   |                                                          |
| <ul style="list-style-type: none"><li>• Lecture transparencies</li><li>• Script in Englisch (H.-H. Wehmann and A. Schlachetzki)</li><li>• Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(Stuttgart, 1998) ISBN: 3-519-06167-8</li><li>• Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (Berlin, 1991) ISBN: 3-540-53873-9</li><li>• Werner Prost: Technologie der III/V-Halbleiter, Springer (Berlin, 1997) ISBN. 3-540-62804-5</li><li>• Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (Stuttgart, 2004) ISBN: 3-519-30149-0</li></ul> |                          |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                          |                   |                                                          |
| Language German or English                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                          |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                            |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                            |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                         | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Semiconductor Technology                                                                                                                                                                                                                                                                                                                          | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner (1998)<br>Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (1991)<br>Werner Prost: Technologie der III/V-Halbleiter, Springer (1997)<br>Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (2004)<br>Ausführliches Skript in Englisch Vorlesungsfolien |            |                  |                 |
| Semiconductor Technology                                                                                                                                                                                                                                                                                                                          | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                 |            |                  |                 |
| Übungsmaterial wird verteilt.                                                                                                                                                                                                                                                                                                                     |            |                  |                 |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Integrated Circuits for Biomedical Applications |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2420190                                         | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                 | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | only in the winter term                         | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1                                               | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4 / 5,0                                         | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 150                                             |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 56                                              | Self studying (h) | 94                                                       |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                 |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Oral exam (30 min) or written exam (90 min)     |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                 |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                 |                   |                                                          |
| <ul style="list-style-type: none"><li>- Introduction to biomedical applications</li><li>- Biosensing principles (physical, electrical and electrochemical)</li><li>- Basic biomedical circuits: transimpedance and instrumentation amplifiers, oscillators, ADCs/DACs</li><li>- Basic circuits for Power Management (DCDC, LDO, Rectifier)</li><li>- Self-powering and energy storage (e.g. biofuel cell sensing, energy harvesting)</li><li>- Wireless Power Transfer (WPT) for implantable devices</li><li>- Circuits for ultra-low power data transmission</li><li>- Circuits for electrochemical sensing (potentiometric and amperometric)</li><li>- Examples of potentiometric biosensors (pH, K+, Na+, Ca+ etc) and iontophoresis</li><li>- Circuits for Impedance Spectroscopy</li><li>- Radar-based Imaging for Breast Cancer Detection</li><li>- Circuits for Electrical Impedance Tomography</li><li>- Resonance-based dielectric sensors (e.g. for glucose detection)</li><li>- Circuits for cochlear implants</li></ul> |                                                 |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                 |                   |                                                          |
| Upon completion of this module, the students will acquire knowledge about integrated circuits for various biomedical applications and obtain a deep understanding about circuit techniques for design of analog integrated circuits for biomedical applications (e.g. HF-oscillators for glucose sensing).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |
| “Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems”, Rahul Sarpeshkar, Cambridge University Press, 2010<br>“Power Management Integrated Circuits (Devices, Circuits, and Systems)”, M. Hella, P. Mercier, CRC Press, 2016<br>“Introduction to Biosensors From Electric Circuits to Immunosensors”, J.-Y. Yoon, Springer 2016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                 |                   |                                                          |



|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                               |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                            | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
|                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Lecture          | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
| Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems, Rahul Sarpeshkar, Cambridge University Press, 2010<br>Power Management Integrated Circuits (Devices, Circuits, and Systems), M. Hella, P. Mercier, CRC Press, 2016<br>Introduction to Biosensors From Electric Circuits to Immunosensors, J.-Y. Yoon, Springer 2016 |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                      | 2,0        | Exercise         | english german  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
| Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems, Rahul Sarpeshkar, Cambridge University Press, 2010<br>Power Management Integrated Circuits (Devices, Circuits, and Systems), M. Hella, P. Mercier, CRC Press, 2016<br>Introduction to Biosensors From Electric Circuits to Immunosensors, J.-Y. Yoon, Springer 2016 |            |                  |                 |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                              |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Mixed Signal Design                                                                                                                                                          |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2420000040                                                                                                                                                                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | only in the summer term                                                                                                                                                      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                                                                                                                                                                            | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 3 / 5,0                                                                                                                                                                      | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 150                                                                                                                                                                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 42                                                                                                                                                                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                              |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | The modules Analog Integrated Circuits, Analog RF CMOS Integrated Circuits and Phase-Locked Loops and Frequency Synthesis are a useful addition to the topic of this module. |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Oral exam (30 min) or written exam (90 min)                                                                                                                                  |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                              |                   |                                                          |
| <p>This course provides an in-depth exploration of mixed-signal integrated circuit design, with a primary focus on Analog-to-Digital Converters (ADCs) and Digital-to-Analog Converters (DACs)—the essential components that bridge the analog and digital worlds.</p> <p>Students will learn how to analyze, design, and evaluate the performance of data converters from both a system-level and circuit-level perspective. The course begins with a foundational overview of mixed-signal systems and key data converter performance metrics such as resolution, signal-to-noise ratio (SNR), and linearity. Following a review of circuit design fundamentals, lectures focus on the theoretical and practical principles of quantization, sampling, and noise in data converters. The course then systematically examines DAC architectures including binary-weighted, R-2R ladder, segmented, and current-steering types, with emphasis on speed, area, and matching trade-offs. Subsequent lectures discuss ADC architectures, covering flash, pipeline, successive approximation (SAR), and delta-sigma types. For each architecture, students will explore circuit implementation strategies, trade-offs in power and resolution, and real-world applications. Additionally, transistor-level implementation of the most commonly encountered sub-blocks such as comparators, reference circuits, opamps or frequency generation circuits will be discussed. The course culminates with a comprehensive look at simulation, verification, and test methodologies.</p> |                                                                                                                                                                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                              |                   |                                                          |
| <p>The students have knowledge of the architecture and fundamental operating principles of analog-to-digital converters and digital-to-analog converters. They understand and can assess key performance parameters such as resolution, signal-to-noise ratio, and linearity for various converter architectures. This enables them to identify the appropriate converter architecture for specific application areas (e.g., modern communication systems or biomedical sensors) and to design it at the circuit level.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                              |                   |                                                          |
| Marcel Pelgrom. Analog-to-Digital Conversion. ISBN: 9783319831756                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                              |                   |                                                          |

Behzad Razavi, *Analysis and Design of Data Converters*, ISBN: 9781009602235

Shanti Pavan, Richard Schreier, Gabor C. Temes, *Understanding Delta-Sigma Data Converters*, ISBN: 9781119258278

R. Jacob Baker, *Circuit Design, Layout and Simulation*, ISBN: 9781119481515



#### Related courses

#### Rules for the choice of courses

#### Compulsory attendance

| Name of the course | SWS | Eventtype | Language |
|--------------------|-----|-----------|----------|
|--------------------|-----|-----------|----------|

|                     |     |         |         |
|---------------------|-----|---------|---------|
| Mixed Signal Design | 2,0 | Lecture | english |
|---------------------|-----|---------|---------|

#### Literature

Marcel Pelgrom, *Analog-to-Digital Conversion*, ISBN: 9783319831756

Behzad Razavi, *Analysis and Design of Data Converters*, ISBN: 9781009602235

Shanti Pavan, Richard Schreier, Gabor C. Temes, *Understanding Delta-Sigma Data Converters*, ISBN: 9781119258278

R. Jacob Baker, *Circuit Design, Layout and Simulation*, ISBN: 9781119481515

|                     |     |          |         |
|---------------------|-----|----------|---------|
| Mixed Signal Design | 1,0 | Exercise | english |
|---------------------|-----|----------|---------|

#### Literature

Marcel Pelgrom, *Analog-to-Digital Conversion*, ISBN: 9783319831756

Behzad Razavi, *Analysis and Design of Data Converters*, ISBN: 9781009602235

Shanti Pavan, Richard Schreier, Gabor C. Temes, *Understanding Delta-Sigma Data Converters*, ISBN: 9781119258278

R. Jacob Baker, *Circuit Design, Layout and Simulation*, ISBN: 9781119481515

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Neuromorphic Computing & Engineering |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2420000010                           | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                      | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | only in the summer term              | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1                                    | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 3 / 5,0                              | Module owner      | Prof. Dr. Thomas Kämpfe                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 150                                  |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 42                                   | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                      |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Oral exam (30 min)                   |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                      |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                      |                   |                                                          |
| <p>Neuromorphic computing is an approach which is inspired by the structure and function of human brains. Neuromorphic computers are based on Silicon devices which use physical artificial neurons and synapses to apply computations. In recent times, the term neuromorphic has been used to describe analog, digital, mixed-mode analog/digital VLSI, and software systems that implement models of neural systems. The implementation of neuromorphic computing on the hardware level can be realized by oxide-based resistive or ferro-electric memristors.</p> <p>The lecture presents the principles of biological computation and their implementation in hardware. Basic building blocks of neuromorphic technology are presented. The implications for the development of novel information processing technologies are outlined.</p> |                                      |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                      |                   |                                                          |
| After successfully completing the module, students will have understand the principles of biological computation. They will know how to implement them in hardware. They will have basic skills in applying neuromorphic engineering.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                      |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                      |                   |                                                          |
| <ul style="list-style-type: none"><li>• Neuromorphic Computing for Computer Scientists</li><li>• Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601</li><li>• Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. <a href="https://www.nature.com/articles/s41928-023-01053-4">https://www.nature.com/articles/s41928-023-01053-4</a></li><li>• C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 <a href="https://www.nature.com/articles/s43588-021-00184-y">https://www.nature.com/articles/s43588-021-00184-y</a></li></ul>                                                                                                               |                                      |                   |                                                          |



| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |           |          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----------|----------|
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |           |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |     |           |          |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |     |           |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |     |           |          |
| Name of the course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | SWS | Eventtype | Language |
| Neuromorphic Computing & Engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2,0 | Lecture   | english  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |     |           |          |
| <ul style="list-style-type: none"> <li>• Neuromorphic Computing for Computer Scientists</li> <li>• Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601</li> <li>• Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. <a href="https://www.nature.com/articles/s41928-023-01053-4">https://www.nature.com/articles/s41928-023-01053-4</a></li> <li>• C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 <a href="https://www.nature.com/articles/s43588-021-00184-y">https://www.nature.com/articles/s43588-021-00184-y</a></li> </ul> |     |           |          |
| Neuromorphic Computing & Engineering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1,0 | Exercise  | english  |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |     |           |          |
| <ul style="list-style-type: none"> <li>• Neuromorphic Computing for Computer Scientists</li> <li>• Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601</li> <li>• Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. <a href="https://www.nature.com/articles/s41928-023-01053-4">https://www.nature.com/articles/s41928-023-01053-4</a></li> <li>• C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 <a href="https://www.nature.com/articles/s43588-021-00184-y">https://www.nature.com/articles/s43588-021-00184-y</a></li> </ul> |     |           |          |

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|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Phase-Locked Loops and Frequency Synthesis  |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2420000020                                  | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                             | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the winter term                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1                                           | Institution       | Institut für CMOS Design                                 |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3 / 5,0                                     | Module owner      | Prof. Dr. Vadim Issakov                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 150                                         |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 42                                          | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Basic knowledge in analogue circuits        |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | oral exam (30 min) or written exam (60 min) |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                             |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             |                   |                                                          |
| <div>- System overview</div> <div>- Jitter and phase noise</div> <div>- Basic PLL architectures</div> <div>- Analog integer PLL</div> <div>- Digital integer PLL</div> <div>- Fractional PLL</div> <div>- Clock data recovery</div> <div>- Delay locked loop</div> <div>- Numerically controlled oscillator</div> <div>- Software PLL</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                             |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             |                   |                                                          |
| <p>Upon completion of the module, students will have a comprehensive understanding of the fundamentals and advanced concepts of phase-locked loops (PLLs) and frequency synthesis. They will be familiar with the systematic architecture of various PLL types, including analog and digital integer PLLs as well as fractional PLLs. Students will understand the causes and effects of jitter and phase noise, and will be able to evaluate and minimize them. They will be acquainted with specialized circuits such as Costas loops, delay locked loops (DLL), numerically controlled oscillators (NCOs), and software-based PLL implementations. The knowledge they acquire enables students to independently research related topics and apply theory to practice. This allows them to analyze and solve practical problems independently.</p> |                                             |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                             |                   |                                                          |
| <p>Best, Roland E., Phase-Locked Loops: Design, Simulation, and Applications. 6. Auflage, McGraw-Hill Education, 2007</p> <p>Behzad Razavi "Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level", Cambridge University Press, 2020</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                             |                   |                                                          |



|                                                                                                                               |            |                  |                 |
|-------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                        |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                        |            |                  |                 |
|                                                                                                                               |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                  |            |                  |                 |
|                                                                                                                               |            |                  |                 |
| <b>Name of the course</b>                                                                                                     | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Phase-Locked Loops and Frequency Synthesis                                                                                    | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                             |            |                  |                 |
| Best, Roland E., Phase-Locked Loops: Design, Simulation, and Applications. 6. Auflage, McGraw-Hill Education, 2007.           |            |                  |                 |
| Behzad Razavi "Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level", Cambridge University Press, 2020 |            |                  |                 |
| Phase-Locked Loops and Frequency Synthesis                                                                                    | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                             |            |                  |                 |
| Best, Roland E., Phase-Locked Loops: Design, Simulation, and Applications. 6. Auflage, McGraw-Hill Education, 2007.           |            |                  |                 |
| Behzad Razavi "Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level", Cambridge University Press, 2020 |            |                  |                 |

| Title                                                                                                                                                                                                                                                                              | Sensor Technology                                                                                                                                             |                   |                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                             | 2413000040                                                                                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                          |                                                                                                                                                               | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                 | only in the summer term                                                                                                                                       | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                    | 1                                                                                                                                                             | Institution       | Institut für Halbleitertechnik                           |
| Hours per Week / ECTS                                                                                                                                                                                                                                                              | 3 / 5,0                                                                                                                                                       | Module owner      |                                                          |
| Workload (h)                                                                                                                                                                                                                                                                       | 150                                                                                                                                                           |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                               | 42                                                                                                                                                            | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                            |                                                                                                                                                               |                   |                                                          |
| Recommended requirements                                                                                                                                                                                                                                                           | Attending Materials & Device Analysis; Fundamentals of NanoOptics; Integrated Circuits for Biomedical Applications in addition to the lecture is recommended. |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                          | Written exam (60 min) or oral exam (30 min)                                                                                                                   |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                 | Project work (design project), either with written assignment or final presentation/colloquium                                                                |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                           |                                                                                                                                                               |                   |                                                          |
|                                                                                                                                                                                                                                                                                    |                                                                                                                                                               |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                            |                                                                                                                                                               |                   |                                                          |
|                                                                                                                                                                                                                                                                                    |                                                                                                                                                               |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                         |                                                                                                                                                               |                   |                                                          |
| Core Texts:                                                                                                                                                                                                                                                                        |                                                                                                                                                               |                   |                                                          |
| <ul style="list-style-type: none"><li>• Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010</li><li>• Horowitz &amp; Hill: The Art of Electronics (2nd ed), CUP, 1989</li></ul>                                                                                        |                                                                                                                                                               |                   |                                                          |
| Supplementary:                                                                                                                                                                                                                                                                     |                                                                                                                                                               |                   |                                                          |
| <ul style="list-style-type: none"><li>• Pallás-Areny &amp; Webster: Analog Signal Processing, Wiley, 1999</li><li>• MIT OCW readings &amp; lecture notes from MAS#836 Sensor Technologies</li><li>• Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)</li></ul> |                                                                                                                                                               |                   |                                                          |



|                                                                                                                                                                                                                                                                                        |            |                  |                 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                 |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                 |            |                  |                 |
|                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                           |            |                  |                 |
|                                                                                                                                                                                                                                                                                        |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Sensor Technology                                                                                                                                                                                                                                                                      | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                      |            |                  |                 |
| Core Texts:                                                                                                                                                                                                                                                                            |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010</li> <li>• Horowitz &amp; Hill: The Art of Electronics (2nd ed), CUP, 1989</li> </ul>                                                                                         |            |                  |                 |
| Supplementary:                                                                                                                                                                                                                                                                         |            |                  |                 |
| <ul style="list-style-type: none"> <li>• Pallás-Areny &amp; Webster: Analog Signal Processing, Wiley, 1999</li> <li>• MIT OCW readings &amp; lecture notes from MAS#836 Sensor Technologies</li> <li>• Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)</li> </ul> |            |                  |                 |
| Sensor Technology                                                                                                                                                                                                                                                                      | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                      |            |                  |                 |
| Project and sensor type-specific; s. lecture for literature and provided articles.                                                                                                                                                                                                     |            |                  |                 |



| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                  |                   |                               |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4211480                                                                                                          | Module version    | V2                            |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                  | Language          |                               |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the winter term                                                                                          | Teaching unit     | Carl-Friedrich-Gauß-Fakultät  |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 Semester                                                                                                       | Institution       |                               |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4 / 5,0                                                                                                          | Module owner      | Prof. Dr. Guillermo Payá Vayá |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 150                                                                                                              |                   |                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 56                                                                                                               | Self studying (h) | 94                            |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                  |                   |                               |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | The modules “Hardware-Software-Systeme” and “Hardware Praktikum” are recommended as preparation for this course. |                   |                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Graded work (examination): Written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam.                |                   |                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                  |                   |                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                  |                   |                               |
| <ul style="list-style-type: none"><li>- Introduction to VLSI Design</li><li>- Fundamentals of CMOS Transistors</li><li>- Fabrication and Layout of CMOS Integrated Circuits</li><li>- CMOS Circuits (Combinational and Sequential Logic Circuits)</li><li>- Design Methodologies</li><li>- Issues in Chip Design</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                  |                   |                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                  |                   |                               |
| This lecture deals with the design of digital circuits in CMOS technology. The students learn about alternative techniques for the realization of basic circuits as well as their manufacturing and design process. By using practical examples, various forms of implementation of integrated circuits are discussed and current challenges of today's chip development in modern semiconductor technologies are presented. After completing the module, students are able to independently design VLSI chips.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                  |                   |                               |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                  |                   |                               |
| <ul style="list-style-type: none"><li>- D. Harris, N. Weste: "CMOS VLSI Design.", Pearson Education, Inc (2010).</li><li>- H. Veendrick: "Nanometer CMOS ICs ", Springer, 2007</li><li>- Y. Taur, T. Ning: "Fundamentals of Modern VLSI Devices", Cambridge University Press, 1998</li><li>- J.M. Rabaey, A. P. Chandrakasan, and B. Nikoli#, “Digital Integrated Circuits: a Design Perspective”. Vol. 7. Upper Saddle River, NJ: Pearson Education, 2003.</li><li>- J. Uyemura: "CMOS Logic Circuit Design", Kluwer Academic Publishers, 1999</li><li>- K. Reifschneider: "CAE-gestützte IC-Entwurfsmethoden", Prentice Hall, 1998</li><li>- K. Itoh: "VLSI Memory Chip Design", Springer, 2001</li><li>- D. Jansen: "Handbuch der Electronic Design Automation", Carl Hanser Verlag, 2002</li><li>- R. J. Baker, H. W. Li, D. E. Byce: "CMOS Circuit Design. Layout, and Simulation", IEEE Press 1998</li><li>- R. Hunter, T. Johnson: "VHDL", Springer, 2007</li><li>- D. Perry: "VHDL", McGraw-Hill, 1998</li><li>- P. Ashenden: "The Designers Guide to VHDL", Morgan Kaufmann, 2002</li></ul> |                                                                                                                  |                   |                               |
| Further references will be announced in the course.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                  |                   |                               |



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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| VLSI-Design                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |            |                  |                 |
| <p>- D. Harris, N. Weste: "CMOS VLSI Design.", Pearson Education, Inc (2010). - H. Veen-<br/>drick: "Nanometer CMOS ICs ", Springer, 2007 - Y. Taur, T. Ning: "Fundamentals of<br/>Modern VLSI Devices", Cambridge University Press, 1998 - J.M. Rabaey, A. P. Chandra-<br/>kasan, and B. Nikoli#, "Digital Integrated Circuits: a Design Perspective". Vol. 7. Upper<br/>Saddle River, NJ: Pearson Education, 2003. - J. Uyemura: "CMOS Logic Circuit Design",<br/>Kluwer Academic Publishers, 1999 - K. Reifschneider: "CAE-gestützte IC-Entwurfsme-<br/>thoden", Prentice Hall, 1998 - K. Itoh: "VLSI Memory Chip Design", Springer, 2001 - D.<br/>Jansen: "Handbuch der Electronic Design Automation", Carl Hanser Verlag, 2002 - R. J.<br/>Baker, H. W. Li, D. E. Byce: "CMOS Circuit Design. Layout, and Simulation", IEEE Press<br/>1998 - R. Hunter, T. Johnson: "VHDL", Springer, 2007 - D. Perry: "VHDL", McGraw-Hill,<br/>1998 - P. Ashenden: "The Designers Guide to VHDL", Morgan Kaufmann, 2002 Further<br/>references will be announced in the course.</p> |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2,0        | Exercise         | english         |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                        |                   |                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | VLSI-Lab                                                                                                                                                                                                                                                                                               |                   |                               |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 4211490                                                                                                                                                                                                                                                                                                | Module version    |                               |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                        | Language          |                               |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | only in the summer term                                                                                                                                                                                                                                                                                | Teaching unit     | Carl-Friedrich-Gauß-Fakultät  |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1                                                                                                                                                                                                                                                                                                      | Institution       |                               |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 4 / 5,0                                                                                                                                                                                                                                                                                                | Module owner      | Prof. Dr. Guillermo Payá Vayá |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 150                                                                                                                                                                                                                                                                                                    |                   |                               |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 56                                                                                                                                                                                                                                                                                                     | Self studying (h) | 94                            |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                        |                   |                               |
| Recommended requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | The modules “Hardware-Software-Systems” and “Hardware Praktikum” are recommended as preparation for the laboratory. In addition, the modules “VLSI Design” and “Verification, Validation and Testing of ASIC Designs” are recommended to attend in parallel during the realization of this laboratory. |                   |                               |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                        |                   |                               |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | non-graded work: successful completion of the given tasks; presentation of 30 minutes                                                                                                                                                                                                                  |                   |                               |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                        |                   |                               |
| <p>The Chip Design Laboratory is divided into three successive phases. All phases of the laboratory consist of interactive self-study and seminars. The latter provide students with the knowledge necessary to work on the tasks in small groups in self-study. During the independently organized work in the groups on a defined task (self-study), a research associate of the institute checks the progress and gives assistance if necessary. Phase 0: Chip conception and specification The hardware modules to be implemented in phase 1 are designed and specified in small groups during this phase. This phase is based on the target application to be executed on the hardware. The application as well as the hardware modules in form of a microcontroller, peripheral modules and co-processors are selected and all necessary features of these are summarized and documented in this phase. Phase 1: Module implementation and verification At the beginning of phase 1, the students implement individual hardware modules specified in phase 0, i.e., a microcontroller, peripheral modules and co-processors, in small groups using VHDL. The knowledge from previous courses, which is required for VHDL design and testbenches (with System-C), is refreshed and extended in two seminars. Phase 2: Chip design and prototyping After the module development, different groups perform: • functional verification and emulation using a FPGA evaluation board (in-circuit emulation), • performing a complete ASIC synthesis and back-end flow based on a library of standard cells, and • porting a small application onto the system...</p> |                                                                                                                                                                                                                                                                                                        |                   |                               |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                        |                   |                               |
| <p>The Chip-Design-Lab is a practical laboratory for the design of integrated digital circuits. In this laboratory, students design digital circuits using a RISC-V microcontroller with</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                        |                   |                               |

peripheral modules. During the different phases of the lab, the students design, specify, implement and verify digital circuits with hardware description languages, industrial EDA tools, System-C testbenches and hardware test setups. The qualification goals taught in this laboratory are successful project work in the field of digital circuit design from the specification to the in-circuit test of the designed circuit. The students gain knowledge about project planning, development work and teamwork. At the same time, students acquire specialized knowledge in their own work with used tools and hardware description languages. The goal is the successful and self-developed completion of the project and the exchange of the knowledge gained in teamwork.

#### Literature

- Rabaey, J. M., Chandrakasan, A. P., & Nikoli#, B. (2003). Digital integrated circuits: a design perspective (Vol. 7). Upper Saddle River, NJ: Pearson Education.
- Weste, N. H., & Harris, D. (2015). CMOS VLSI design: a circuits and systems perspective. Pearson Education India.
- Brunvand, E. (2010). Digital VLSI chip design with Cadence and Synopsys CAD tools. Addison-Wesley.
- Ashenden, P. J. (2010). The designer's guide to VHDL. Morgan Kaufmann.
- Ashenden, P. (2008). Digital Design: An Embedded Systems Approach Using VHDL. Morgan Kaufmann.

Further references will be announced in the course.



| Related courses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |            |          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------|----------|
| Rules for the choice of courses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |            |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |            |          |
| Compulsory attendance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |            |          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |     |            |          |
| Name of the course                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | SWS | Eventtype  | Language |
| VLSI-Lab                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 4,0 | Internship | english  |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |            |          |
| <ul style="list-style-type: none"> <li>• Rabaey, J. M., Chandrakasan, A. P., &amp; Nikoli#, B. (2003). Digital integrated circuits: a design perspective (Vol. 7). Upper Saddle River, NJ: Pearson Education.</li> <li>• Weste, N. H., &amp; Harris, D. (2015). CMOS VLSI design: a circuits and systems perspective. Pearson Education India.</li> <li>• Brunvand, E. (2010). Digital VLSI chip design with Cadence and Synopsys CAD tools. Addison-Wesley.</li> <li>• Ashenden, P. J. (2010). The designer's guide to VHDL. Morgan Kaufmann.</li> <li>• Ashenden, P. (2008). Digital Design: An Embedded Systems Approach Using VHDL. Morgan Kaufmann.</li> </ul> <p>Further references will be announced in the course.</p> |     |            |          |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Emerging Memory Technologies |                   |                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 2420000000                   | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                              | Language          | english                                                  |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | only in the winter term      | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1                            | Institution       | Institut für Neuromorphic Computing                      |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 3 / 5,0                      | Module owner      | Prof. Dr. Thomas Kämpfe                                  |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 150                          |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 42                           | Self studying (h) | 108                                                      |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                              |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Oral exam (30 min)           |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                              |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                              |                   |                                                          |
| <p>In this course, students will learn about the leading contenders for post-silicon storage-class and main memory technologies. Decades of research have yielded several efficient memory device working principles, including phase-change of the structure (PCM), materials conversion (OxRAM), ion diffusion (CBRAM), magnetic properties (STT-MRAM, MTJ), and ferroelectricity (FRAM, FeFET). Currently, these memory technologies are transitioning from research to industry, and are predicted to have at least niche applications in the ever-growing hardware market. Some technologies, such as PCM, may even eventually surpass silicon-based flash memory, providing better performance and unique features.</p> <p>Students will have the opportunity to compare emerging memory technologies with state-of-the-art SSD Flash, DRAM, and SRAM, as well as evaluate their potential. Through critical thinking discussions, students will acquire important skills for assessing the strengths and limitations of these emerging technologies.</p> |                              |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                              |                   |                                                          |
| <p>After successfully completing the module, students will understand the biological principles of neural information processing and their differences to the von Neumann architecture. They know the basic methods for hardware implementation of neuromorphic systems. They will also be able to design simple neuromorphic algorithms for specific applications and analyze their performance. Finally, they will be able to evaluate the strengths, weaknesses and current developments of neuromorphic systems and assess their potential for various application areas.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                              |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                              |                   |                                                          |
| <ul style="list-style-type: none"><li>• Neuromorphic Computing for Computer Scientists</li><li>• Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601</li><li>• Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. <a href="https://www.nature.com/articles/s41928-023-01053-4">https://www.nature.com/articles/s41928-023-01053-4</a></li><li>• C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 <a href="https://www.nature.com/articles/s43588-021-00184-y">https://www.nature.com/articles/s43588-021-00184-y</a></li></ul>                                                                                                                                                                                                                                                                                                                              |                              |                   |                                                          |



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| <b>Related courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Compulsory attendance</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                  |                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |            |                  |                 |
| <b>Name of the course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |
| Emerging Memory Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2,0        | Lecture          | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <ul style="list-style-type: none"> <li>• T. Schenk et al., Memory technology – a primer for material scientists. Reports on Progress in Physics, 2020, 83, 086501. <a href="https://doi.org/10.1088/1361-6633/ab8f86">https://doi.org/10.1088/1361-6633/ab8f86</a></li> <li>• W. Zhang et al., Designing crystallization in phase- change materials for universal memory and neuro-inspired computing. Nature Reviews Materials, 2019, 4, 150. <a href="https://doi.org/10.1038/s41578-018-0076-x">https://doi.org/10.1038/s41578-018-0076-x</a></li> <li>• D. Lencer et al., Design Rules for Phase-Change Materials in Data Storage Applications. Advanced Materials, 2011, 23 (18), 2030. <a href="https://doi.org/10.1002/adma.201004255">https://doi.org/10.1002/adma.201004255</a></li> <li>• S. W. Fong et al., Phase-Change Memory – Towards a Storage-Class Memory. IEEE Transactions on Electron Devices, 2017, 64 (11), 4374. <a href="https://doi.org/10.1109/TED.2017.2746342">https://doi.org/10.1109/TED.2017.2746342</a></li> <li>• S. Yuasa et al., Materials for spin-transfer-torque magnetoresistive random-access memory. MRS Bulletin, 2018, 43, 352. <a href="https://doi.org/10.1557/mrs.2018.93">https://doi.org/10.1557/mrs.2018.93</a></li> <li>• S. Ikegawa et al., Magnetoresistive Random Access Memory: Present and Future. IEEE Transactions on Electron Devices, 2020, 67 (4), 1407. <a href="https://doi.org/10.1109/TED.2020.2965403">https://doi.org/10.1109/TED.2020.2965403</a></li> <li>• H.-S. Philip Wong et al., Metal-Oxide RRAM. Proceedings of the IEEE, 2012, 100 (6), 1951. <a href="https://doi.org/10.1109/JPROC.2012.2190369">https://doi.org/10.1109/JPROC.2012.2190369</a></li> <li>• M. N. Kozicki et al., Conductive bridging random access memory – materials, devices and applications. Semiconductor Science and Technology, 2016, 31 (11), 113001. <a href="https://doi.org/10.1088/0268-1242/31/11/113001">https://doi.org/10.1088/0268-1242/31/11/113001</a></li> </ul> |            |                  |                 |
| Emerging Memory Technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1,0        | Exercise         | english         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            |                  |                 |
| <ul style="list-style-type: none"> <li>• T. Schenk et al., Memory technology – a primer for material scientists. Reports on Progress in Physics, 2020, 83, 086501. <a href="https://doi.org/10.1088/1361-6633/ab8f86">https://doi.org/10.1088/1361-6633/ab8f86</a></li> <li>• W. Zhang et al., Designing crystallization in phase- change materials for universal memory and neuro-inspired computing. Nature Reviews Materials, 2019, 4, 150. <a href="https://doi.org/10.1038/s41578-018-0076-x">https://doi.org/10.1038/s41578-018-0076-x</a></li> <li>• D. Lencer et al., Design Rules for Phase-Change Materials in Data Storage Applications. Advanced Materials, 2011, 23 (18), 2030. <a href="https://doi.org/10.1002/adma.201004255">https://doi.org/10.1002/adma.201004255</a></li> <li>• S. W. Fong et al., Phase-Change Memory – Towards a Storage-Class Memory. IEEE Transactions on Electron Devices, 2017, 64 (11), 4374. <a href="https://doi.org/10.1109/TED.2017.2746342">https://doi.org/10.1109/TED.2017.2746342</a></li> <li>• S. Yuasa et al., Materials for spin-transfer-torque magnetoresistive random-access memory. MRS Bulletin, 2018, 43, 352. <a href="https://doi.org/10.1557/mrs.2018.93">https://doi.org/10.1557/mrs.2018.93</a></li> <li>• S. Ikegawa et al., Magnetoresistive Random Access Memory: Present and Future. IEEE Transactions on Electron Devices, 2020, 67 (4), 1407. <a href="https://doi.org/10.1109/TED.2020.2965403">https://doi.org/10.1109/TED.2020.2965403</a></li> <li>• H.-S. Philip Wong et al., Metal-Oxide RRAM. Proceedings of the IEEE, 2012, 100 (6), 1951. <a href="https://doi.org/10.1109/JPROC.2012.2190369">https://doi.org/10.1109/JPROC.2012.2190369</a></li> <li>• M. N. Kozicki et al., Conductive bridging random access memory – materials, devices and applications. Semiconductor Science and Technology, 2016, 31 (11), 113001. <a href="https://doi.org/10.1088/0268-1242/31/11/113001">https://doi.org/10.1088/0268-1242/31/11/113001</a></li> </ul> |            |                  |                 |

## Laboratory Courses

| Title                                                                                                                                                             | Lab Master Electrical Engineering                                                                                              |                   |                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                            | 2499500                                                                                                                        | Module version    |                                                          |
| Shorttext                                                                                                                                                         |                                                                                                                                | Language          | german                                                   |
| Frequency of offer                                                                                                                                                | every term                                                                                                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                   | 2                                                                                                                              | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                             | 1 / ,0                                                                                                                         | Module owner      |                                                          |
| Workload (h)                                                                                                                                                      | 300                                                                                                                            |                   |                                                          |
| Class attendance (h)                                                                                                                                              |                                                                                                                                | Self studying (h) |                                                          |
| Compulsory requirements                                                                                                                                           |                                                                                                                                |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                      |                                                                                                                                |                   |                                                          |
| Course achievement                                                                                                                                                | Labs and/or software practical courses (§ 4 para. 11) totalling 8-10 credits, not more than 5 credits in minor specialisation. |                   |                                                          |
| Contents                                                                                                                                                          |                                                                                                                                |                   |                                                          |
| The individual description of the course applies in each case. Additional notes and comments in the individual course descriptions have to be taken into account. |                                                                                                                                |                   |                                                          |
| Objective qualification                                                                                                                                           |                                                                                                                                |                   |                                                          |
|                                                                                                                                                                   |                                                                                                                                |                   |                                                          |
| Literature                                                                                                                                                        |                                                                                                                                |                   |                                                          |
|                                                                                                                                                                   |                                                                                                                                |                   |                                                          |



## Related courses

### Rules for the choice of courses

Courses totalling 8-10 credits (Master Electrical Engineering) and 5-10 credits (Master Industrial Engineering Specialized in Electrical Engineering) have to be selected from the available laboratories/practical courses.

Labs can have 1 to 5 credits and are offered as "Labor" (L), "Übung" (Ü) or "Praktikum" (P). The individual description of the course applies in each case. Additional notes and comments in the individual course descriptions have to be taken into account.

### Compulsory attendance

|                    |     |           |          |
|--------------------|-----|-----------|----------|
| Name of the course | SWS | Eventtype | Language |
|--------------------|-----|-----------|----------|

|                                                                                                                                                                                                                                                                                       |     |            |                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------|----------------|
| Electronics measurement internship                                                                                                                                                                                                                                                    | 3,0 | Internship | german         |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |     |            |                |
| Internship script                                                                                                                                                                                                                                                                     |     |            |                |
|                                                                                                                                                                                                                                                                                       | 3,0 | Laboratory | german         |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |     |            |                |
| P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)<br>H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)<br>J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)<br>J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig) |     |            |                |
|                                                                                                                                                                                                                                                                                       | 4,0 | Laboratory | german         |
|                                                                                                                                                                                                                                                                                       | 3,0 | Laboratory | german         |
| Lab Semiconductor Technology I                                                                                                                                                                                                                                                        | 3,0 | Laboratory | german         |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |     |            |                |
| Skript                                                                                                                                                                                                                                                                                |     |            |                |
| Lab Semiconductor Technology II                                                                                                                                                                                                                                                       | 3,0 | Laboratory | english german |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |     |            |                |
| Skript zum Herunterladen.                                                                                                                                                                                                                                                             |     |            |                |
|                                                                                                                                                                                                                                                                                       | 3,0 | Laboratory | german         |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |     |            |                |
| Skript                                                                                                                                                                                                                                                                                |     |            |                |
| Laboratory practical course indoor lighting                                                                                                                                                                                                                                           | 2,0 | Laboratory | german         |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |     |            |                |
| DIN 5035-5                                                                                                                                                                                                                                                                            |     |            |                |
|                                                                                                                                                                                                                                                                                       | 2,0 | Internship | german         |
|                                                                                                                                                                                                                                                                                       | 2,0 | Internship | german         |
|                                                                                                                                                                                                                                                                                       | 2,0 | Internship | german         |
|                                                                                                                                                                                                                                                                                       | 1,0 | Laboratory | english        |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |     |            |                |
| Skript zum Praktikum                                                                                                                                                                                                                                                                  |     |            |                |
|                                                                                                                                                                                                                                                                                       | 4,0 | Internship | german         |
|                                                                                                                                                                                                                                                                                       | 4,0 | Internship | german         |
|                                                                                                                                                                                                                                                                                       | 5,0 | Internship | german         |
| <b>Literature</b>                                                                                                                                                                                                                                                                     |     |            |                |
| J. Liebeherr und M. El Zarki,: Mastering Networks -An Internet Lab Manual-, Pearson, 2004, ISBN: 0-201-78134-4                                                                                                                                                                        |     |            |                |



|                                                                                                                                                                              |     |            |         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------|---------|
|                                                                                                                                                                              | 4,0 | Internship | german  |
| <b>Literature</b>                                                                                                                                                            |     |            |         |
| J. Liebeherr und M. El Zarki,: Mastering Networks -An Internet Lab Manual-, Pearson, 2004, ISBN: 0-201-78134-4                                                               |     |            |         |
|                                                                                                                                                                              | 2,0 | Internship | german  |
| <b>Literature</b>                                                                                                                                                            |     |            |         |
| J. Liebeherr und M. El Zarki,: Mastering Networks -An Internet Lab Manual-, Pearson, 2004, ISBN: 0-201-78134-4                                                               |     |            |         |
|                                                                                                                                                                              | 5,0 | Internship | english |
|                                                                                                                                                                              | 5,0 | Internship | german  |
| <b>Literature</b>                                                                                                                                                            |     |            |         |
| Skript                                                                                                                                                                       |     |            |         |
|                                                                                                                                                                              | 4,0 | Internship | german  |
| Innovative Energy Systems                                                                                                                                                    | 2,0 | Internship | german  |
|                                                                                                                                                                              | 2,0 | Internship | german  |
|                                                                                                                                                                              | 2,0 | Internship | german  |
|                                                                                                                                                                              | 2,0 | Laboratory | german  |
| <b>Literature</b>                                                                                                                                                            |     |            |         |
| siehe Vorlesung                                                                                                                                                              |     |            |         |
|                                                                                                                                                                              | 2,0 | Laboratory | german  |
| <b>Literature</b>                                                                                                                                                            |     |            |         |
| siehe Vorlesung                                                                                                                                                              |     |            |         |
|                                                                                                                                                                              | 2,0 | Laboratory | german  |
| <b>Literature</b>                                                                                                                                                            |     |            |         |
| siehe Vorlesung                                                                                                                                                              |     |            |         |
|                                                                                                                                                                              | 2,0 | Laboratory | german  |
| <b>Literature</b>                                                                                                                                                            |     |            |         |
| siehe Vorlesung                                                                                                                                                              |     |            |         |
|                                                                                                                                                                              | 2,0 | Laboratory | german  |
| <b>Literature</b>                                                                                                                                                            |     |            |         |
| siehe Vorlesung                                                                                                                                                              |     |            |         |
|                                                                                                                                                                              | 4,0 | Internship | german  |
| <b>Literature</b>                                                                                                                                                            |     |            |         |
| Skripte (Download: <a href="https://www.tu-braunschweig.de/ifn/lehre/praktika-und-labore/skripte">https://www.tu-braunschweig.de/ifn/lehre/praktika-und-labore/skripte</a> ) |     |            |         |
|                                                                                                                                                                              | 3,0 | Laboratory | german  |

|                                                                                                                                                                                                                                                                                                                     |     |            |                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------|----------------|
|                                                                                                                                                                                                                                                                                                                     | 4,0 | Laboratory | german         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                   |     |            |                |
| - R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001 - C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006 - I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016                                                                                            |     |            |                |
|                                                                                                                                                                                                                                                                                                                     | 3,0 | Internship | german         |
|                                                                                                                                                                                                                                                                                                                     | 5,0 | Internship | english        |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                   |     |            |                |
| <ul style="list-style-type: none"> <li>• Book: Network of Things Engineering (NoTE) Lab</li> <li>• Herausgeber: Springer; 1st ed. 2023 Edition (10. Januar 2023)</li> <li>• Sprache: Englisch</li> <li>• Gebundene Ausgabe: 240 Seiten</li> <li>• ISBN-10: 3031206347</li> <li>• ISBN-13: 978-3031206344</li> </ul> |     |            |                |
|                                                                                                                                                                                                                                                                                                                     | 5,0 | Internship | german         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                   |     |            |                |
| <ul style="list-style-type: none"> <li>• Book: Network of Things Engineering (NoTE) Lab</li> <li>• Herausgeber: Springer; 1st ed. 2023 Edition (10. Januar 2023)</li> <li>• Sprache: Englisch</li> <li>• Gebundene Ausgabe: 240 Seiten</li> <li>• ISBN-10: 3031206347</li> <li>• ISBN-13: 978-3031206344</li> </ul> |     |            |                |
| Computer Lab Pattern Recognition                                                                                                                                                                                                                                                                                    | 4,0 | Laboratory | english german |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                   |     |            |                |
| <p>Christopher M. Bishop, Nasser M. Nasrabadi, "Pattern Recognition and Machine Learning", Springer 2006</p> <p>Ian Goodfellow, Yoshua Bengio, Aaron Courville, "Deep Learning", MIT Press 2016</p>                                                                                                                 |     |            |                |
| electrotechnical laboratory practical course specialization battery technologies                                                                                                                                                                                                                                    | 3,0 | Internship | german         |
| Computer Network Engineering Lab - CNE Lab                                                                                                                                                                                                                                                                          | 5,0 | Internship | english        |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                   |     |            |                |
| <p>For literature, we will use the Mastering Networks book and the instructions based on it.</p> <p>Liebeherr, Jorg, and Magda El Zarki. Mastering Networks: An Internet Lab Manual. Addison-Wesley Longman Publishing Co., Inc., 2003.</p>                                                                         |     |            |                |
| Network of Things Engineering Domain Lab – NoTED Lab                                                                                                                                                                                                                                                                | 5,0 | Internship | english        |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                   |     |            |                |
| For literature, we will use the NoteLab script, or the instructions based on it.                                                                                                                                                                                                                                    |     |            |                |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |     |            |                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------|----------------|
| Practical course in lasers and coherent optics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 3,0 | Laboratory | german         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |            |                |
| - Skript zum Praktikum<br>- zusätzlich kann auf die vorlesungsbegleitende Literatur zurückgegriffen werden. Ergänzende Unterlagen werden während des Praktikums verteilt.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |            |                |
| Low-Power Embedded Systems Laboratory                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 5,0 | Laboratory | english        |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |            |                |
| Tutorials and example code will be provided on Gitlab.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |     |            |                |
| Further literature:<br>- Edward A. Lee and Sanjit A. Seshia: Introduction to Embedded Systems, A Cyber- Physical Systems Approach, Second Edition, MIT Press, ISBN 978- 0-262-53381-2, 2017.<br>- P. Marwedel: Embedded System Design, Springer, ISBN 978- 3-030-60909-2, 2021.<br>- G.C. Buttazzo: Hard Real- Time Computing Systems. Springer Verlag, ISBN 978- 1-4614-0676-1, 2011.<br>- M. Wolf: Computers as Components – Principles of Embedded System Design. Morgan Kaufman Publishers, ISBN 978-0-128-05387-4, 2016.<br>- Avelino J. Gonzalez: Computer Programming in C for Beginners, Springer, ISBN 978-3-030-50752-7, 2020.<br>- Joseph Yiu. The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors. Newnes, 2013. |     |            |                |
| Laboratory AI safety assurance in automated driving                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4,0 | Laboratory | german         |
| Laboratory: AI applications in automated driving                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 4,0 | Internship | german         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 5,0 | Internship | german         |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |            |                |
| J. Liebeherr und M. El Zarki,: Mastering Networks -An Internet Lab Manual-, Pearson, 2004, ISBN: 0-201-78134-4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |            |                |
| Autonomous Drone Tracking                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 5,0 | Internship | english        |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |            |                |
| Tutorials and example codes will be provided on StudIP.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |     |            |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 5,0 | Internship | english german |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |            |                |
| Tutorials and example codes will be provided on StudIP.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |     |            |                |
| Cadence Lab                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3,0 | Internship | english german |
| <b>Literature</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |     |            |                |
| B. Razavi – <i>Design of Analog CMOS Integrated Circuits</i><br>Cadence Documentation (Virtuoso User Guides)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |     |            |                |
| laboratory - electrotechnical laboratory practical course specialization battery technologies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 2,0 | Laboratory | german         |

**Extracurricular Qualifications**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                       |                   |                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Industrial Internship                                                                                                                                                                                                 |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2499040                                                                                                                                                                                                               | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                       | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | every term                                                                                                                                                                                                            | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1                                                                                                                                                                                                                     | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 8 / 12,0                                                                                                                                                                                                              | Module owner      |                                                          |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 360                                                                                                                                                                                                                   |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                       | Self studying (h) |                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                       |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                       |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Final presentation in accordance with the separate regulations "Internship guidelines of the Faculty of Electrical Engineering, Information Technology, Physics" in the version valid at the beginning of the course. |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                       |                   |                                                          |
| individual; requirements according to internship guidelines                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                       |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                       |                   |                                                          |
| <p>The industrial internship provides in-depth preparation for professional life by working directly in an industrial company for at least 10 weeks. Students gain insight into organisational and operational processes and structures as well as into the work methods of engineering activities in industrial companies. Within the wide variety and breadth of structural areas (e.g. research, development, production, sales,...) and fields of activity (e.g. hardware or software development, production planning, quality assurance, sales, (project) management,...) in an industrial company, an exemplary selection with in-depth familiarisation with one or a few of these areas or fields is expected.</p> <p>The aim of the module is the further development of action patterns and techniques appropriate to the situation and task as well as the further development and adaptation of the methodological skills taught during the course in the engineering solution of technical problems. In addition, students deepen their interdisciplinary knowledge and skills (e.g. discussion and negotiation skills, presentation techniques, documentation, etc.), for example by participating in meetings or by being involved in conceptual, planning or management tasks. They also carry out their own engineering activities (e.g. in conceptual planning, development or quality assurance) independently and represent their own interests. In doing so, they apply the technical knowledge and skills acquired during their studies to practical tasks in an industrial environment.</p> <p>The activities carried out as part of the industrial internship must be presented in an ungraded presentation. The presentation, including preparation and follow-up work, is worth 3 credits within the 12 credits of this module.</p> |                                                                                                                                                                                                                       |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                       |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                       |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                       |                   |                                                          |

The activities carried out as part of the industrial internship must be presented in an ungraded presentation. The presentation, including preparation and follow-up work, is worth 3 credits within the 12 credits of this module. The workload is exclusively at the location of the industrial partner, usually outside the university.



| <b>Related courses</b>                 |     |           |          |
|----------------------------------------|-----|-----------|----------|
| <b>Rules for the choice of courses</b> |     |           |          |
|                                        |     |           |          |
| <b>Compulsory attendance</b>           |     |           |          |
|                                        |     |           |          |
| Name of the course                     | SWS | Eventtype | Language |

|                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Title                                                                                                                                                                                                                                            | Master's Team Project                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                   |                                                          |
| Number                                                                                                                                                                                                                                           | 2499520                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                               | every term                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                  | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                            | 0 / 8,0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Module owner      |                                                          |
| Workload (h)                                                                                                                                                                                                                                     | 240                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                             | 160                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Self studying (h) | 80                                                       |
| Compulsory requirements                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                                          |
| Expected performance/ Type of examination                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                                          |
| Course achievement                                                                                                                                                                                                                               | The Master's team project corresponds to the examination requirements of the draft (§ 9 APO). A written project plan must be submitted for the Master's team project at the beginning, which is to be updated during the course of the project. The comparison between initial planning and actual progress must be presented and justified in the final report. The results of the Master's team project must be summarized in a report in which the individual contributions of the project participants are identified. Furthermore, the results must be presented in a presentation (§ 9 APO). |                   |                                                          |
| Contents                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                                          |
| individual                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                                          |
| The Master's team project is generally completed in groups of at least three students who carry out the design, analysis, construction or simulation of an electrical or information technology system using an overarching topic as an example. |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                                          |
| Literature                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                                          |
|                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                                          |



|                                                                  |            |                  |                 |
|------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                           |            |                  |                 |
| <b>Rules for the choice of courses</b>                           |            |                  |                 |
| The Master's team project can replace the industrial internship. |            |                  |                 |
| <b>Compulsory attendance</b>                                     |            |                  |                 |
|                                                                  |            |                  |                 |
| <b>Name of the course</b>                                        | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Professionalisation                                                                                                                            |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 2499560                                                                                                                                        | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | every term                                                                                                                                     | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2                                                                                                                                              | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 0 / 9,0                                                                                                                                        | Module owner      |                                                          |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 360                                                                                                                                            |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                | Self studying (h) |                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | according to the requirements of the course taken from the pool selection;<br><br>Seminar presentation: presentation according to § 4 para. 14 |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                |                   |                                                          |
| individual                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                |                   |                                                          |
| <p>Key qualifications will be achieved in the following fields:</p> <p>- Action-oriented courses, scientific cultures</p> <p>For this purpose, courses from the overall program (pool) of interdisciplinary courses at the Technische Universität Braunschweig are to be selected. The type of examination or coursework and the number of credit points will be announced individually for each module.</p> <p><a href="https://www.tu-braunschweig.de/studium-lehre/im-studium/lehrveranstaltungen">https://www.tu-braunschweig.de/studium-lehre/im-studium/lehrveranstaltungen</a></p> <p>The Dean of Studies ensures that a list of available courses is published each semester, in which recommendations for particularly practice-oriented courses are given.</p> <p>- Seminar lecture</p> <p>Seminar presentation at one of the institutes of the EITP faculty involved in the degree program. An independent examination of a topic with the inclusion and evaluation of relevant literature as well as the presentation and communication of the results in an oral presentation and in a subsequent discussion.</p> |                                                                                                                                                |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                |                   |                                                          |

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|--------------------------------------------------------------------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                                                                           |            |                  |                 |
| <b>Rules for the choice of courses</b>                                                           |            |                  |                 |
| A total of 8-12 credits has to be achieved. The seminar presentation of 3 credits is compulsory. |            |                  |                 |
| <b>Compulsory attendance</b>                                                                     |            |                  |                 |
|                                                                                                  |            |                  |                 |
| <b>Name of the course</b>                                                                        | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                            |                   |                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| Final Module                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                            |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                            |                   |                                                          |
| Title                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Master's Thesis                                                                                                                                                                                                                                                                            |                   |                                                          |
| Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 2499510                                                                                                                                                                                                                                                                                    | Module version    |                                                          |
| Shorttext                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                            | Language          | english german                                           |
| Frequency of offer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | every term                                                                                                                                                                                                                                                                                 | Teaching unit     | Fakultät für Elektrotechnik, Informationstechnik, Physik |
| Module duration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1                                                                                                                                                                                                                                                                                          | Institution       |                                                          |
| Hours per Week / ECTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 0 / 30,0                                                                                                                                                                                                                                                                                   | Module owner      | Studiendekan Elektrotechnik                              |
| Workload (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 900                                                                                                                                                                                                                                                                                        |                   |                                                          |
| Class attendance (h)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                            | Self studying (h) |                                                          |
| Compulsory requirements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                            |                   |                                                          |
| Expected performance/<br>Type of examination                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <ul style="list-style-type: none"><li>• Preparation of the Master's thesis (28 credits)</li><li>• Presentation (according to § 4 para. 14 BPO) (2 credits)</li></ul> <p>The assessment of the presentation is included in the overall grade of the final module with double weighting.</p> |                   |                                                          |
| Course achievement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                            |                   |                                                          |
| Contents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                            |                   |                                                          |
| individual                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                            |                   |                                                          |
| Objective qualification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                            |                   |                                                          |
| <p>With the successful completion of the final thesis (§ 14 APO) and the presentation, the student demonstrates that he/she is able to work independently on a problem from the chosen subject area using scientific methods within a specified period of time. The qualification objectives of the degree program (Annex 1, § 2 APO) are reflected in the implementation and results of the final thesis with regard to the following components:</p> <ul style="list-style-type: none"><li>• Independent familiarisation with and scientific methodical processing of a topic fundamentally relevant to further development and research in the field of electrical engineering</li><li>• Literature research and presentation of the state of the art</li><li>• Development of new solution approaches for a scientific problem</li><li>• Presentation of the approach and results in the form of a paper</li><li>• Presentation of the main results in a comprehensible form</li><li>• Consolidation and refinement of key qualifications: management of an own project, presentation techniques and rhetorical skills</li></ul> |                                                                                                                                                                                                                                                                                            |                   |                                                          |
| Literature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                            |                   |                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                            |                   |                                                          |
| Remark                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                            |                   |                                                          |
| The Master's thesis is credited with 28 credits and the presentation with 2 credits; the assessment of the presentation is included in the overall grade of the final module with double weighting.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                            |                   |                                                          |



|                                        |            |                  |                 |
|----------------------------------------|------------|------------------|-----------------|
| <b>Related courses</b>                 |            |                  |                 |
| <b>Rules for the choice of courses</b> |            |                  |                 |
|                                        |            |                  |                 |
| <b>Compulsory attendance</b>           |            |                  |                 |
|                                        |            |                  |                 |
| <b>Name of the course</b>              | <b>SWS</b> | <b>Eventtype</b> | <b>Language</b> |

