Description of the degree program

Electrical Engineering and Information Technology (Master)

PO 5

Date: 25.02.2026

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Compulsory Module

Title	Ambits of Electromagnetic Field Theory		
Number	2419110	**Module version**	
Shorttext	ET-IEMV-11	**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
Hours per Week / ECTS	4 / 5,0	**Module owner**	
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

- Energetic considerations, Poynting theorem, equivalent circuit
- Potentials in the dynamic case, Hertzian dipole and radiation, approximations for the field descriptions
- Analytical calculation methods and examples, numerical field calculation

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.

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
	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

- Potential formalism: scalar potential and vector potential
- Energy considerations, Poynting theorem
- Potentials for the dynamic case, Hertzian dipole and radiation, approximations in fielddescriptions
- Field theory in quantum mechanics: electromagnetic interactions in Schrödinger theory
- Field theory in microelectronics: Propagators and Green's function, effective and fieldtheory for antenna design

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.

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

Advanced Applications of Field Theory	2,0	Lecture	english
Literature			
D.J. Griffiths: Electrodynamics J.D. Jackson: Classical Electrodynamics A.Enders: Electromagnetic Fields (TU Braunschweig)			

Advanced Applications of Field Theory	2,0	Exercise	english
Literature			
D.J. Griffiths: Electrodynamics J.D. Jackson: Classical Electrodynamics A.Enders: Electromagnetic Fields (TU Braunschweig)			

Major Specialisation: Information Technologies - Compulsory Elective Modules

Title	Coding Theory		
Number	2424420	**Module version**	
Shorttext	ET-NT-42	**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

- Introduction
- Fundamentals of information theory
- Basics of channel coding
- Single-error-correcting block codes
- Block codes for correcting burst errors
- Convolutional codes
- Special coding techniques

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
H.Rohling: Einführung in die Informations- und Codierungstheorie, Teubner
R.Togneri, C.J.S. deSilva: Fundamentals of Information Theory and Coding Design, Chapman&Hall/CRC
H.Schneider-Obermann: Kanalcodierung, Vieweg

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Coding Theory	2,0	Lecture	english german

Literature

Vorlesungsskript
H. Rohling: Einführung in die Informations- und Codierungstheorie, Teubner
R. Togneri, C. J. S. de Silva: Fundamentals of Information Theory and Coding Design, Chapman&Hall/CRC
H. Schneider-Obermann: Kanalcodierung, Vieweg

Name of the course	SWS	Eventtype	Language
Coding Theory	1,0	Exercise	english german

Literature

siehe Vorlesung

Name of the course	SWS	Eventtype	Language
Computer exercise on Coding Theory	1,0	Laboratory	english german

Title	Electromagnetic Theory for Microwave Engineering		
Number	2415490	**Module version**	
Shorttext	ET-IHF-49	**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/ Type of examination	written examination 90 minutes or oral examination 30 minutes or homework assignments or semester project assignment (§ 4)		
Course achievement			

Contents

- Theory of time-harmonic electromagnetic fields (Maxwell’s equations, wave equation, Poynting’s theorem, uniqueness theorem, reciprocity)
- Methods of calculation (vector potentials, Lorenz gauge, solution of the (in)homogeneous wave equation, source integrals, Green’s function)
- Eigenmodes of waveguides, surface waves, leaky waves
- Radiation fields (Huygens’ principle, image theory, Fresnel and Fraunhofer approximations)
- Introduction to the numerical solution of electromagnetic problems (FDTD, method of moments, eigenmode expansion)
- Exemplary implementation of solution methods in Matlab or Python
- simulation of electromagnetic structures using commercial 3D-EM-software

Objective qualification

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.
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.

Literature

Harrington, Time-harmonic Electromagnetic Fields, Wiley & Sons, ISBN 047120806X
Unger, Elektromagnetische Theorie für die Hochfrequenztechnik I + II, Hüthig, ISBN 377851573X, ISBN 3778515748
Pozar, Microwave Engineering, Wiley & Sons, ASIN B001QA4I9C

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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
	1,0	Practical exercise	german

Title	Image Communication		
Number	2424270	**Module version**	
Shorttext	ET-NT-27	**Language**	german
Frequency of offer	every term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	2	**Institution**	Institut für Nachrichtentechnik
Hours per Week / ECTS	4 / 6,0	**Module owner**	Prof. Dr. Ulrich Reimers
Workload (h)	180		
Class attendance (h)	56	**Self studying (h)**	124
Compulsory requirements			
Expected performance/ Type of examination	Oral exam (30 min)		
Course achievement			

Contents

Image communication is among the most relevant methods in communication and is a companion in our daily life. Even cellular communications is currently dominated by the transmission of video data – it´s amount is significantly higher than the amount of speech or general data such as those for web browsing.
It is the goal of this module to comprehensively cover all aspects of image communication. Therefore the fundamentals of image representation are presented as well as the science of colour representation, or production systems from camera to studio technology, and displays. Digital image and video coding and digital transmission are emphasized specifically.

Image Communication I:
1. Introduction
2. Image representation – fundamentals, system theory, formats
3. Colourimetry and colour science
4. Technology of image acquisition
5. Technology in the production studioImage

Communication II:
6. Analogue video transmission
7. Digital image and video coding
8. Digital video transmission
9. Displays and receivers

Objective qualification

Upon successful conclusion of the module, students will be prepared to write a Bachelor's or Master's thesis in the field of image communication and/or to co-operate in research and development projects in the university or in industry.

Literature

H. Lang: Farbwiedergabe in den Medien, Muster-Schmidt Verlag, 1995
U. Reimers: DVB-Digitale Fernsehtechnik: Datenkompression und Übertragung, Springer-Verlag, 3. Auflage, 2008
U. Schmidt: Professionelle Videotechnik, Springer-Verlag, 4. Auflage, 2005

G. Mahler: Die Grundlagen der Fernsehtechnik, Springer-Verlag, 2005
Remark
Lecture in German except section 8 which is presented in English

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

	2,0	Lecture	german
Literature			
H.Lang: Farbmetrik und Farbfernsehen, Oldenbourg Verlag, 1978 R.Mäusl: Fernsehtechnik, Hüthig Verlag, 1995 U.Reimers: Digitale Fernsehtechnik - Datenkompression und Übertragungstechnik, Springer Verlag, 3. Auflage, 2007 U.Schmidt: Professionelle Videotechnik, Springer Verlag 2000 A.N.Netravali, B.G.Haskell: Digital Pictures - Representation and Compression, Plenum Press, 1991			

	2,0	Lecture	german
Literature			
- H.Lang: Farbwiedergabe in den Medien, Muster-Schmidt Verlag Göttingen Zürich, 1995 - U.Reimers: DVB-Digitale Fernsehtechnik: Datenkompression und Übertragung, Springer Verlag, 3. Auflage, 2008 - U.Schmidt: Professionelle Videotechnik, Springer Verlag, 4. Auflage, 2005 - G.Mahler: Die Grundlagen der Fernsehtechnik, Springer Verlag Berlin, 2005			

Title	Information Theory		
Number	2424720	**Module version**	
Shorttext	ET-NT-72	**Language**	
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/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

- Basics from probability theory
  - Event, probability, random variable, random vector, stochastic process, convergence of random series, convergence theorems
- Basics from information theory
  - Measures for discrete random varaibles: entropy, conditional entropy, relativ entropy, mutual information, conditional mutual information, inequalities
  - Measures for continous random variables: differential entropy, conditional differential entropy, relative entropy, mutual information, inequalities
  - Measure for random series
  - Typical sequences and asymptotic equipartition property
- Source and source coding
  - Definition and properties
  - Source coding for discrete memoryless sources (fixed and variable-length)
  - Selected source codes: Morse, Huffman, Shannon-Fano-Elias
- Data transmission and channel capacity
  - Discrete memoryless channel: channel coding theorem
  - Discrete memoryless channel with state: channel capacities
  - Gaussian channel: model and channel coding theorem
  - Bandlimited Gaussian channel, vector valued channels

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.
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

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Information Theory	2,0	Lecture	german

Literature

- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008. - 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

Name of the course	SWS	Eventtype	Language
Information Theory	1,0	Exercise	german

Literature

- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008. - 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

Title	New Architecture and Protocols in Communication Networks		
Number	2416760	**Module version**	
Shorttext	ET-IDA-76	**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

- Introduction to broadband communication
- Broadband access networks
- Optical Networks
- Control and management of broadband networks
- Wireless broadband networks
- Applications of broadband networks

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

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Lecture	german
Literature			
Include latest research papers, tutorials and industrial standards			

	1,0	Exercise	german

Title	Optimization and Game Theory for Communications		
Number	2424700	**Module version**	
Shorttext	ET-IFR-42	**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/ Type of examination	Written exam (120) or oral exam (30 min), according to number of participants		
Course achievement			

Contents

Linear programming and resource allocation
Convex programming and power control
Global programming and interference networks
Non-cooperative games and distributed resource allocation
Coalitional games and ad-hoc networks

Objective qualification

The student can recognize, classify, and formulate optimization problems which typically occur in communications. They know diverse algorithms for solving the problems and are able to apply them successfully for programming problems related to current research in communications. The students know the basic mathematical tools in game theory and are able to apply them to model and solve cooperative and non-cooperative communication systems.

Literature

Bertsekas, Dimitri P. (2003). Convex Analysis and Optimization, Athena Scientific.
Boyd, S. and Vandenberghe, L. (2004). Convex Optimization, Cambridge University Press, (pdf).
Tuy, Hoang (2016). Convex Analysis and Global Optimization, Kluwer Academic.
M. J. Osborne und A. Rubinstein: A Course in Game Theory, The MIT Press, 1994.
D. Fudenberg und J. Tirole: Game Theory, The MIT Press, 1991. # M. J. Holler und G. Illing: Einführung in die Spieltheorie, Springer, 4. Auflage, 2000.
A. B. MacKenzie und L. A. DaSilva: Game Theory for Wireless Engineers (Synthesis Lectures on Communications), Morgan & Claypool Publishers, 2006.

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

	2,0	Lecture	german
Literature			
? Bertsekas, Dimitri P. (2003). Convex Analysis and Optimization, Athena Scientific. ? Boyd, S. and Vandenberghe, L. (2004). Convex Optimization, Cambridge University Press, (pdf). ? Tuy, Hoang (2016). Convex Analysis and Global Optimization, Kluwer Academic. ? M.?J. Osborne und A. Rubinstein: A Course in Game Theory, The MIT Press, 1994. ? D. Fudenberg und J. Tirole: Game Theory, The MIT Press, 1991. ? M.?J. Holler und G. Illing: Einführung in die Spieltheorie, Springer, 4. Auflage, 2000. ? A.?B. MacKenzie und L.?A. DaSilva: Game Theory for Wireless Engineers (Synthesis Lectures on Communications), Morgan & Claypool Publishers, 2006.			

	1,0	Exercise	english
Literature			
? Bertsekas, Dimitri P. (2003). Convex Analysis and Optimization, Athena Scientific. ? Boyd, S. and Vandenberghe, L. (2004). Convex Optimization, Cambridge University Press, (pdf). ? Tuy, Hoang (2016). Convex Analysis and Global Optimization, Kluwer Academic. ? M.?J. Osborne und A. Rubinstein: A Course in Game Theory, The MIT Press, 1994. ? D. Fudenberg und J. Tirole: Game Theory, The MIT Press, 1991. ? M.?J. Holler und G. Illing: Einführung in die Spieltheorie, Springer, 4. Auflage, 2000. ? A.?B. MacKenzie und L.?A. DaSilva: Game Theory for Wireless Engineers (Synthesis Lectures on Communications), Morgan & Claypool Publishers, 2006.			

Major Specialisation: Information Technologies - Elective Modules

Title	Quality Assurance and Optimization		
Number	2411220	**Module version**	
Shorttext	ET-EMG-22	**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
Systematic and random measurement uncertainties/errors Noise and noise analysis
Determination of measurement uncertainty according to GUM
Fundamentals of applied statistics: distribution functions, estimation theory, hypothesis tests, error propagation
Equalisation calculation, regression analysis
Statistical design of experiments
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
- W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall 1991), ISBN 978-0023805523
- O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag 1978), ISBN 978-3411001194
- N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons 1977), ISBN 978-0471017561 und 978-0471017578
- Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig 1974, im Bibliotheksbestand
- 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

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	2,0	Lecture	german
Literature			
• #E. Schrüfer: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall) • O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag) • N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons) • Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig • B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH) • G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)			
	2,0	Exercise	german
Literature			
• #E. Schrüfer: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall) • O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag) • N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons) • Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig • B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH) • G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)			

Title	Automated Road Vehicles: from Assistance to Autonomy		
Number	2412620	Module version	
Shorttext	ET-IFR-62	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

-probabilistic knowledge representation for driver assistance and vehicle guidance systems
- radar-based and visual machine perception
- machine situation detection and behavioural decision-making
- human-machine-interaction
- design and test of driver assistance and vehicle guidance systems

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

- 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

Remark

The course “Automotive Systems Engineering” provides helpful background knowledge for this course; however, it is not a mandatory prerequisite for participation.

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Related courses			
Rules for the choice of courses			
Only one of the three modules ET-IFR-42, ET-IFR-58, ET-IFR-62 can be chosen.			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Lecture	german
Literature			
- 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 - R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111 - M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964 - S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics			

	2,0	Exercise	german
Literature			
- 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 - R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111 - M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964 - S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics			

Title	Integrated Circuits		
Number	2413280	**Module version**	
Shorttext	ET-IHT-28	**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. Vadim Issakov
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Expected performance/ Type of examination	oral exam (20 min)		
Course achievement			

Contents

The module provides an overview of the operation, design, and technology of integrated electronic circuits in microelectronics.

- Introduction
- Basic digital circuits
- MOS and CMOS
- Silicon wafer manufacturing
- MOSFET process technology
- Nanolithography
- Etching techniques and oxidation
- Design automation, design rules, and assembly techniques
- Back-end technologies
- Modern developments: Memory technologies

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

Lecture slides and short script
J.M.Rabaey, A.Chandrakasan, B. Nikolic, Digital Integrated Circuits
Prentice Hall Electronics and VLSI Series, 2002 ISBN: 8120322576
A. Schlachetzki, Integrierte Schaltungen, Teubner, 1978, (as copy at IHT) ISBN: 3-519-03070-5
D. Widmann, H. Mader, H. Friedrich, Technologie Hochintegrierte Schaltungen, Springer,1996 ISBN:3540593578
W. Prost, Technologie der III/V Halbleiter, Springer, 1997 ISBN: 3540628045

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

	2,0	Lecture	german
Literature			
Vorlesungsfolien und Kurzskript K.-H. Cordes, A. Waag, N. Heuck : Integrierte Schaltungen; Pearson Studium, 2010 J.M.Rabaey, A.Chandrakasan, B. Nikolic, Digital Integrated Circuits Prentice Hall Electronics and VLSI Series, 2003, 1996 A. Schlachetzki, Integrierte Schaltungen, Teubner, 1978, (als Kopie im IHT) D. Widmann, H. Mader, H. Friedrich, Technologie Hochintegrierte Schaltungen, Springer,1996 W. Prost, Technologie der III/V # Halbleiter, Springer, 1997			

	1,0	Exercise	german
Literature			
K.-H. Cordes, A. Waag, N. Heuck : Integrierte Schaltungen; Pearson Studium, 2010			

Title	Packaging and Interconnection Technology		
Number	2413390	Module version	
Shorttext	ET-IHT-39	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

- Open wiring, bread board, printed circuit board
- Thick film technologies, substrates, screen printing and pastes, thin film technology, photolithography
- Surface mount technology, components, housing forms, modern developments (TAB, BGA, flip chip, CSP, MCM)
- Power modules, special requirements
- Cooling, basics and problems, air cooling, liquid cooling
- Thermomechanical stresses and reliability, basics, examples
- Soldering
- Adhesive bonding
- Wire bonding
- Direct copper bonding
- Low-temperature joining technology

Objective qualification

After completing the module electronic packaging, the students will have
- a basic understanding of the most important processes for assembling and joining electronic devices and components
- the ability to select suitable processes for packaging in the manufacture of semiconductor modules
- in-depth knowledge and practical experience in the use, analysis and evaluation of methods of electronic packaging

Literature

W. Scheel (Hrsg.): Baugruppentechnologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) ISBN: 3-341-01100-5
H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01097-1
H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Hybridträger (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01099-8
M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiesbaden, 1991) ISBN: 3-528-06392-0

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

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

	1,0	Exercise	german
Literature			
Unterlagen werden verteilt.			

	2,0	Lecture	german
Literature			
W. Scheel (Hrsg.): Baugruppentechnologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994) H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Hybridträger (Verlag Technik, Berlin, Saulgau, 1994) M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiebaden, 1991)			

Title	Semiconductor Technology		
Number	2413420	**Module version**	
Shorttext	ET-IHT-42	**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/ Type of examination	Oral exam 30 min		
Course achievement			

Contents

- physical and chemical basics
- manufacturing of single crystals and wafers
- epitaxial crystal growth processes and crystal defects
- doping processes
- semiconductor measurement technology
- planar technology
- basics of photolithography, deposition processes for dielectrics and etching processes

Objective qualification

After completing the semiconductor technology module, students have:
- an understanding of the basic manufacturing technologies of semiconductors as well as components and integrated circuits made from them.
- the ability to recognize the principles of the most modern manufacturing processes in semiconductor technology and their modes of operation
- the ability to analyze and extrapolate trends in semiconductor technology developments

Literature

- Lecture transparencies
- Script in Englisch (H.-H. Wehmann and A. Schlachetzki)
- Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(Stuttgart, 1998) ISBN: 3-519-06167-8
- Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (Berlin, 1991) ISBN: 3-540-53873-9
- Werner Prost: Technologie der III/V-Halbleiter, Springer (Berlin, 1997) ISBN. 3-540-62804-5
- Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (Stuttgart, 2004) ISBN: 3-519-30149-0

Remark

Language German or English

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

Title	Nanotechniques in Microelectronics		
Number	2413460	**Module version**	
Shorttext	ET-IHT-46	**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. Andrey Bakin
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

- introduction, definitions, basics
- nanostructuring
- self-organized nanostructures
- printed electronics
- nanoimprint
- 2D materials
- 3D chip - new generation of integration
- new wiring and cooling concepts
- nanotechnology in joining technology and packaging
- new components with improved properties

Objective qualification

The students are able to assess the applications of nanotechnology in microelectronics and to evaluate the trends in nanotechnology development.

Literature

Slides
Nanostructured Materials and Nanotechnology, ed. Hari Singh Nalwa, Academic Press 2002, ISBN 0 12-513920-9
Nanotechnology for Microelectronics and Optoelectronics, J. Martinez-Duart, R. Martin-Palmer, F. Agullo-Rueda, Elsevier 2006, ISBN-13: 978-0-08-044553-3

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course	SWS	Eventtype	Language
	2,0	Lecture	german
Literature			
# Folien # Nanostructured Materials and Nanotechnology, ed. Hari Singh Nalwa, Academic Press 2002, ISBN 0 12-513920-9 # Nanotechnology for Microelectronics and Optoelectronics, J. Martinez-Duart , R. Martin-Palmer, F. Agullo-Rueda, Elsevier 2006, ISBN-13: 978-0-08-044553-3			
	2,0	Exercise	german

Title	Optical Communications with Lab		
Number	2415220	Module version	
Shorttext	ET-IHF-22	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/ Type of examination	Written exam (120 minutes) or oral exam (30 minutes)		
Course achievement			

Contents

- Optical fibers
- Dispersion, velocities of light
- Coherent modulation
- Coherent receiver
- Laser
- Optical amplifier
- Optoelectronic modulators
- Photodetectors
- Systems of optical communications

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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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language

	2,0	Lecture	german
Literature			
- Skript zur Vorlesung - S. L. Chuang, Physics of Optoelectronic Devices, John Wiley & Sons			

	1,0	Exercise	german

	1,0	Laboratory	english
Literature			
Skript zum Praktikum			

Title	Optoelectronics		
Number	2415290	**Module version**	
Shorttext	ET-IHF-29	**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/ Type of examination	Written exam (90 min) or oral exam (30 min) or presentation		
Course achievement			

Contents

- Propagation of electromagnetic waves in free space and in guiding structures
- Refraction, reflexion, total reflexion at dielectric interfaces
- Optical guiding in film and strip waveguides, mechanisms of losses
- Optical modes and theoretical description
- field distribution in step and gradient profiles, analogy to quantum mechanics
- Periodic structures to distributed feedback: DFB, DBR
- Electrooptical interaction, directional couplers

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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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	Microwave Circuit Design 2 (Nonlinear Circuits)		
Number	2415340	**Module version**	
Shorttext	ET-IHF-34	**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

- Mixers, parametric calculation, modeling of active components
- The Harmonic Balance method including a programming assignment for an exemplary implementation of the method
- Radio frequency diodes (pn varactor, Schottky varactor, IMPATT diode), Gunn element
- Frequency multipliers, harmonic mixers and oscillators, resonators and resonator coupling
- Design of nonlinear microwave circuits using commercial design software

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

	2,0	Lecture	german

Literature

- Skript zur Vorlesung - Pozar, Microwave Engineering, Wiley - Maas, Nonlinear Microwave and RF Circuits, Artech Hoise

	2,0	Exercise	german

	2,0	Internship	german

Title	Antennas and Electromagnetic Radiation		
Number	2415360	**Module version**	
Shorttext	ET-IHF-34	**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

- 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)
- basic antenna structures, characteristic parameters of antennas
- array antennas and beamforming, synthesis of antenna patterns
- aperture antennas, Fourier transformation, horn and slot antennas, parabolic antennas, Physical Optics
- wave propagation, diffraction limit of free-space propagation, static models, radar cross section
- antenna and RCS characterization methods
- modern state of the art and current research topics

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
Unger, Elektromagnetische Theorie für die Hochfrequenztechnik, Hüthig-Verlag, ISBN 377851573X
Pozar, Microwave Engineering, Wiley, ASIN B001QA4I9C

Remark

Prerequisites: Mathematics, Electromagnetic Fields, Fundamentals of Information Technology, Guided Electromagnetic Waves

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
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	ET-IHF-34	**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/ Type of examination	written examination (90 min) or oral examination (30 min) or homework assignments or semester project assignment (§ 4)		
Course achievement			

Contents
- Matching structures, binomial and Chebychev multisection transformers, Bode-Fano criterion - PIN diode, microwave switches and phase shifters - Bipolar transistor, HBT, FET, HEMT, amplifiers, LNA, power amplifiers - Design and realization of microwave filters - Design of linear microwave circuits using commercial design software
Objective qualification
After completion oft he 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

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	1,0	Internship	german

	2,0	Lecture	german

Literature

- Skript zur VL - Pozar, Microwave Engineering, Wiley - Unger, Harth, Hochfrequenz-Halbleiterelektronik, Hirzel

	1,0	Exercise	german

Title	Radar Systems and Signal Processing		
Number	2415450	**Module version**	
Shorttext	Radar-Syst	**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/ Type of examination	oral exam (30 min) or written exam (60 min) or project work		
Course achievement			

Contents

Objective qualification

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.
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.

Literature

Remark

Requirements: it is recommended to have completed the module “RF and Microwave Systems and Circuits”
expected knowledge:
- introduction to RF circuits (S parameters, concept of matching)
- transmission line theory
- antenna and radio transmission basics (dipole antenna, antenna parameters, Friis transmission equation, link budget)

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Related courses

Rules for the choice of courses

Compulsory attendance

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

Title	Nonlinear Photonics		
Number	2415470	**Module version**	
Shorttext	ET-IHF-47	**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

- Basics of linear optics
- 2nd order nonlinear optical effects
- 3rd order nonlinear optical effects
- Nonlinear scattering
- Optical telecommunications
- Nonlinear effects in optical fibers
- Suppression of nonlinear effects
- Applications of nonlinear effects

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

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

Title	Electromagnetic Theory for Microwave Engineering		
Number	2415490	**Module version**	
Shorttext	ET-IHF-49	**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/ Type of examination	written examination 90 minutes or oral examination 30 minutes or homework assignments or semester project assignment (§ 4)		
Course achievement			

Contents

- Theory of time-harmonic electromagnetic fields (Maxwell’s equations, wave equation, Poynting’s theorem, uniqueness theorem, reciprocity)
- Methods of calculation (vector potentials, Lorenz gauge, solution of the (in)homogeneous wave equation, source integrals, Green’s function)
- Eigenmodes of waveguides, surface waves, leaky waves
- Radiation fields (Huygens’ principle, image theory, Fresnel and Fraunhofer approximations)
- Introduction to the numerical solution of electromagnetic problems (FDTD, method of moments, eigenmode expansion)
- Exemplary implementation of solution methods in Matlab or Python
- simulation of electromagnetic structures using commercial 3D-EM-software

Objective qualification

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.
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.

Literature

Harrington, Time-harmonic Electromagnetic Fields, Wiley & Sons, ISBN 047120806X
Unger, Elektromagnetische Theorie für die Hochfrequenztechnik I + II, Hüthig, ISBN 377851573X, ISBN 3778515748
Pozar, Microwave Engineering, Wiley & Sons, ASIN B001QA4I9C

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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
	1,0	Practical exercise	german

Title	Linear photonics with practical course		
Number	2415500	Module version	
Shorttext	ET-IHF-50	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)			

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

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

Title	Computer Architecture 2 - Embedded Systems		
Number	2416060	**Module version**	
Shorttext	ET-IDA-06	**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	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	oral exam (30 minutes)		
Course achievement			

Contents

Specification of digital systems (FSM, statecharts, SDF, ...)

Architectural principles for embedded systems, examples (microcontrollers, digital signal processors)

Implementation:
- Automated circuit synthesis
- Optimising compilers for embedded architectures
- Scheduling in real-time operating systems

Objective qualification

Students will gain an in-depth understanding of the architecture and design of embedded systems. The focus is on formal fundamentals, systematic contexts, algorithms and methods. After completing the module, students will be able to model a given application and specify an adapted computer architecture by means of a hardware-software co-design.

Literature

#- lecture notes
- W. Wolf, Computers As Components
- Principles of Embedded Computing System Design, Morgan Kaufmann Publishers, ISBN 978-0123743978

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	3,0	Lecture	german
	1,0	Exercise	german

Title	Communication Networks for Engineers		
Number	2416490	Module version	
Shorttext	ET-IDA-49	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/ Type of examination	Written exam (90 minutes) or oral exam (30 minutes)		
Course achievement			

Contents

* Basic network sopologies and protocol architectures
* Transmission systems and multiplexing methods
* Selected protocol mechanisms
* LAN protocols
* Basics of the Internet and the IP protocol
* Routing in the Internet
* The TCP protocol and its performance evaluation
* High-speed networks (MPLS, Ethernet and optical networks)
* 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 Prentise Hall, 2004, ISBN: 0-13-183311-1 #
B. Mukherjee, Optical WDM networks, Springer, 2006, ISBN: 0-387-29055-9 #
J. F. Kurose und K. W. Ross, Computer Networking: A Top-Down Approach Featuring the Internet, Addison Wesley, 2005, ISBN: 0-321-26976-4

↑

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

	1,0	Exercise	german
Literature			
* Skript * J.F. Kuruse und K.W. Ross, Computernetze *W. Stallings, Data and Computer Communications			

	2,0	Lecture	german
Literature			
* Skript * J.F. Kuruse und K.W. Ross, Computernetze *W. Stallings, Data and Computer Communications			

Title	Network Security		
Number	2416530	**Module version**	
Shorttext	ET-IDA-53	**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

- Mathematical foundations of cryptology and information security
- Functions of public and secret key cryptology
- Authentication and data security protocols
- Current applications and standards of IP network security
- Current applications and standards of wireless network security
- Network commerce and payment systems
- Selected current advanced network security topics

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.
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

- W. Adi, lecture notes and exercises
- William Stallings, Network Security Essentials: Applications and Standards, 3rd Edition, Prentice Hall, © 2007, ISBN-10: 0-13-238033-1
- Charlie Kaufman, Radia Perlman, Mike Speciner, Network Security: Private Communication in a Public World (2nd edition), Prentice Hall, 2002, ISBN-10: 0130460192

↑

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

	2,0	Lecture	german
Literature			
• W. Adi, Vorlesungsfolien und Übungen. William Stallings, Network Security Essentials: Applications and Standards, 3rd Edition, Prentice Hall, © 2007, ISBN-10: 0-13-238033-1 • Charlie Kaufman, Radia Perlman, Mike Speciner, Network Security: Private Communication in a Public World (2nd edition), Prentice Hall, 2002, ISBN-10: 0130460192			

	1,0	Exercise	german

Title	Performance Evaluation of Communications Network		
Number	2416580	Module version	
Shorttext	ET-IDA-58	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), depending on number of participants		
Course achievement			

Contents

- Modeling of stochastic processes
- Theory of Markoff chains
- Processes and characteristics in communication systems
- Multiservice communication systems
- M/G/1 queueing systems and priorities
- Basics of stochastic simulation

Objective qualification

- Upon completion of this module, students will have a basic understanding of modeling stochastic processes in communication systems.
- Based on the introduced process characteristics, they are able to evaluate and compare systems, and to form their own models.

Literature

Lecture notes
L. Kleinrock, Queuing Systems - Volume I: Theory, John Wiley & Sons, New York, 1975, ISBN: 0-471-49110-1
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.
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.

↑

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

	2,0	Lecture	german
Literature			
# Skript # L. Kleinrock, Queuing Systems # A. Leon-Garcia, Probability and Random Processes for Electrical Engineering			

	1,0	Exercise	german
Literature			
Skript # L. Kleinrock, Queuing Systems # A. Leon-Garcia, Probability and Random Processes for Electrical Engineering			

Title	Advanced Topics in Security		
Number	2416600	**Module version**	
Shorttext	ET-IDA-60	**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/ 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
2. System Security, threats (buffer overflow, race conditions, privilege escalation), classical access control, process containment (Virtual Machines, runtime enforcement, etc.)
3. Software security, secure design, run time security Privacy
4. Advanced Security protocols: Voting Systems, e-Cash systems, Vehicular Security, others ...
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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

Title	Information Technologies for Social Good		
Number	2416720	**Module version**	
Shorttext	ET-IDA-53	**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	oral exam (30 min) or written exam (90 min)		
Course achievement			

Contents

Disaster management of critical IT infrastructures
Prediction and information models for disaster management
Communication network systems for first responders
Bridging the digital divide
Low cost network systems for developing countries
Social networking for social good
IT systems to address climate change
Fundamentals of privacy and anonymity
Cryptography and privacy
Green farming
Smart farm animals
Technologies for domestic animals
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.
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
Book: Advanced ICTs for Disaster Management and Threat Detection: Collaborative and Distributed Frameworks, Edited by Asimakopoulou, Eleana, IGI Press 2010.
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	ET-IDA-76	**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

- Introduction to broadband communication
- Broadband access networks
- Optical Networks
- Control and management of broadband networks
- Wireless broadband networks
- Applications of broadband networks

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

↑

Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language

	2,0	Lecture	german

Literature

Include latest research papers, tutorials and industrial standards

	1,0	Exercise	german

Title	Network-Security		
Number	2416770	**Module version**	
Shorttext	ET-IDA-77	**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

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language

	2,0	Lecture	german
Literature			
Material provided to students in StudIP, including the references noted within			

	1,0	Exercise	german
Literature			
Material provided to students in StudIP, including the references noted within			

Title	Advanced Topics in Network Engineering		
Number	2416780	**Module version**	
Shorttext	ET-IDA-78	**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/ Type of examination	oral exam (30 min)		
Course achievement			

Contents

- Cross Layer Design
- All-IP networks
- Integration of IP and Optical
- Inter-domain Routing
- Networks for Data Centers, Storage and Grid Computing
- Economics, Standards and Regulations in Telecommunications
- Applications of Networking in Energy, Automation and Health Care
- Research Literature, Papers and Surveys

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
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
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.

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

	1,0	Exercise	english
Literature			
Include latest research papers, tutorials and industrial standards			

	2,0	Lecture	english
Literature			
Include latest research papers, tutorials and industrial standards			

Title	Numerical Calculation of Radiation Properties		
Number	2419070	**Module version**	
Shorttext	ET-IEMV-07	**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
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

- quantitative description of radiation properties by special numerical calculation methods
- theoretical concepts of mainstream methods (FE, FD, MoM) and newer approaches (i.a. wavelets)
- criteria of bandwidth and complexity of boundary conditions
- practical sample applications from EMC (absorption in technical materials and biological tissue, shielding and antenna development)

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 #
Matthew N.O. Sadiku, Numerical Techniques in Electromagnetics, CRC Press, Boca Raton, 2001, ISBN 0-8493-1395-3

↑

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	Electromagnetic Compatibility		
Number	2419120	Module version	
Shorttext	ET-IEMV-12	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
Hours per Week / ECTS	3 / 5,0	Module owner	Dr. Harald Spieker
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

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices #
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference #
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection #
- Legal basis, product liability, standardization #
- EMC test engineering #
- Electromagnetic compatibility of biological systems

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

- Lecture notes
- Joachim Franz, EMV – Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

↑

Related courses

Rules for the choice of courses

Either this module or "Electromagnetic Compatibility with Seminar" can be selected.

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
Electromagnetic Compatibility	2,0	Lecture	german
Electromagnetic Compatibility	1,0	Exercise	german

Title	Electromagnetic Compatibility with Seminar		
Number	2419130	**Module version**	
Shorttext	ET-IEMV-13	**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
Hours per Week / ECTS	5 / 6,0	**Module owner**	
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

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection
- Legal basis, product liability, standardization
- EMC test engineering
- Electromagnetic compatibility of biological systems
- Current EMC issues presented in seminar talks

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

- continuously updated script handout
- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

↑

Related courses

Rules for the choice of courses

You can either choose Electromagnetic Compatibility with Seminar **or** Electromagnetic Compatibility (without seminar). The seminar can also be attened in the summer semester after having attended the EMC lecture.

Compulsory attendance

Name of the course	SWS	Eventtype	Language
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	ET-BST-14	**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

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.

The lecture is divided into the following chapters:

- High-frequency amplifier circuits
- Simulation of electronic noise
- Low-noise input amplifiers in CMOS
- Mixer circuits
- HPhase-locked loops (PLLs)
- Voltage-controlled oscillators

Objective qualification

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).

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.
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

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	ET-BST-15	**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

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.

The lecture is divided into the following chapters:
- High frequency amplifier circuits
- Simulation of electronic noise
- Low-noise input amplifiers in CMOS
- Mixer circuits
- Phase-locked loops (PLLs)
- Voltage-controlled oscillators

Objective qualification

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).

Literature

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

↑

Related courses
Rules for the choice of courses
Prerequisite for this module: Circuit Design (ST)
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
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	ET-BST-19	**Language**	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/ Type of examination	Oral exam (30 min) or written exam (90 min)		
Course achievement			

Contents

- Introduction to biomedical applications
- Biosensing principles (physical, electrical and electrochemical)
- Basic biomedical circuits: transimpedance and instrumentation amplifiers, oscillators, ADCs/DACs
- Basic circuits for Power Management (DCDC, LDO, Rectifier)
- Self-powering and energy storage (e.g. biofuel cell sensing, energy harvesting)
- Wireless Power Transfer (WPT) for implantable devices
- Circuits for ultra-low power data transmission
- Circuits for electrochemical sensing (potentiometric and amperometric)
- Examples of potentiometric biosensors (pH, K+, Na+, Ca+ etc) and iontophoresis
- Circuits for Impedance Spectroscopy
- Radar-based Imaging for Breast Cancer Detection
- Circuits for Electrical Impedance Tomography
- Resonance-based dielectric sensors (e.g. for glucose detection)
- Circuits for cochlear implants

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
“Power Management Integrated Circuits (Devices, Circuits, and Systems)”, M. Hella, P. Mercier, CRC Press, 2016
“Introduction to Biosensors From Electric Circuits to Immunosensors”, J.-Y. Yoon, Springer 2016

↑

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

	2,0	Lecture	german
Literature			
?Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems?, Rahul Sarpeshkar, Cambridge University Press, 2010 ?Power Management Integrated Circuits (Devices, Circuits, and Systems)?, M. Hella, P. Mercier, CRC Press, 2016 ?Introduction to Biosensors From Electric Circuits to Immunosensors?, J.-Y. Yoon, Springer 2016			

	2,0	Exercise	german
Literature			
?Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems?, Rahul Sarpeshkar, Cambridge University Press, 2010 ?Power Management Integrated Circuits (Devices, Circuits, and Systems)?, M. Hella, P. Mercier, CRC Press, 2016 ?Introduction to Biosensors From Electric Circuits to Immunosensors?, J.-Y. Yoon, Springer 2016			

Title	Image Communication		
Number	2424270	**Module version**	
Shorttext	ET-NT-27	**Language**	german
Frequency of offer	every term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	2	**Institution**	Institut für Nachrichtentechnik
Hours per Week / ECTS	4 / 6,0	**Module owner**	Prof. Dr. Ulrich Reimers
Workload (h)	180		
Class attendance (h)	56	**Self studying (h)**	124
Compulsory requirements			
Expected performance/ Type of examination	Oral exam (30 min)		
Course achievement			

Contents

Image communication is among the most relevant methods in communication and is a companion in our daily life. Even cellular communications is currently dominated by the transmission of video data – it´s amount is significantly higher than the amount of speech or general data such as those for web browsing.
It is the goal of this module to comprehensively cover all aspects of image communication. Therefore the fundamentals of image representation are presented as well as the science of colour representation, or production systems from camera to studio technology, and displays. Digital image and video coding and digital transmission are emphasized specifically.

Image Communication I:
1. Introduction
2. Image representation – fundamentals, system theory, formats
3. Colourimetry and colour science
4. Technology of image acquisition
5. Technology in the production studioImage

Communication II:
6. Analogue video transmission
7. Digital image and video coding
8. Digital video transmission
9. Displays and receivers

Objective qualification

Upon successful conclusion of the module, students will be prepared to write a Bachelor's or Master's thesis in the field of image communication and/or to co-operate in research and development projects in the university or in industry.

Literature

H. Lang: Farbwiedergabe in den Medien, Muster-Schmidt Verlag, 1995
U. Reimers: DVB-Digitale Fernsehtechnik: Datenkompression und Übertragung, Springer-Verlag, 3. Auflage, 2008
U. Schmidt: Professionelle Videotechnik, Springer-Verlag, 4. Auflage, 2005

G. Mahler: Die Grundlagen der Fernsehtechnik, Springer-Verlag, 2005
Remark
Lecture in German except section 8 which is presented in English

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

	2,0	Lecture	german
Literature			
H.Lang: Farbmetrik und Farbfernsehen, Oldenbourg Verlag, 1978 R.Mäusl: Fernsehtechnik, Hüthig Verlag, 1995 U.Reimers: Digitale Fernsehtechnik - Datenkompression und Übertragungstechnik, Springer Verlag, 3. Auflage, 2007 U.Schmidt: Professionelle Videotechnik, Springer Verlag 2000 A.N.Netravali, B.G.Haskell: Digital Pictures - Representation and Compression, Plenum Press, 1991			

	2,0	Lecture	german
Literature			
- H.Lang: Farbwiedergabe in den Medien, Muster-Schmidt Verlag Göttingen Zürich, 1995 - U.Reimers: DVB-Digitale Fernsehtechnik: Datenkompression und Übertragung, Springer Verlag, 3. Auflage, 2008 - U.Schmidt: Professionelle Videotechnik, Springer Verlag, 4. Auflage, 2005 - G.Mahler: Die Grundlagen der Fernsehtechnik, Springer Verlag Berlin, 2005			

Title	Modelling and Simulation of Mobile Radio Systems		
Number	2424400	**Module version**	
Shorttext	ET-NT-40	**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/ Type of examination	oral exam (20 min) or written exam (90 min)		
Course achievement	Colloquium or lab journal		

Contents
Objective qualification
Literature
Lecture notes M. C. Jeruchim, P. Balaban, K. S. Shanmugan, Simulation of Communication Systems - Modeling, Methodology and Techniques, Kluwer 2000 R. Vaughan, J. B. Andersen, Channels, Propagation and Antennas for Mobile Communications, IEE Electromagnetic Waves Series 2003 J. G. Proakis, M. Saleh, Grundlagen der Kommunikationstechnik, Pearson Studium, 2. Auflage, 2004 M. Pätzold, Mobilfunkkanäle - Modellierung, Analyse und Simulation, Vieweg 1999 O. Beucher, MATLAB und Simulink, Pearson 2002 M. Schiff, Introduction to Communications Simulation, Artech House 2006 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
Literature			
siehe Vorlesung			

	2,0	Lecture	german
Literature			
Skript M.C.Jeruchim, P.Balaban, K.S.Shanmugan: Simulation of Communications - Modeling,			

Title	Planning of Terrestrial Radio Networks		
Number	2424410	**Module version**	
Shorttext	ET-NT-41	**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/ Type of examination	Oral exam (20 minutes) or written exam (90 minutes)		
Course achievement	Colloquium or lab journal		

Contents

Introduction
Radio propagation models
Coverage planning
Planning cellular networks
General principles of cellular network planning
GSM radio network planning
UMTS radio network planning
Planning OFDMA networks

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

- Lecture notes (German and Eglish)
- C. Lüders, Mobilfunksysteme, Vogel-Verlag 2001 #
- N. Geng, W. Wiesbeck, Planungsmethoden für die Mobilkommunikation, Springer-Verlag 1998
- J. Laiho, A. Wacker, T. Novosad, Radio Network Planning and Optimisation for UMTS, Wiley 2002

Remark

This Master's module is also suitable for Bachelor students.

↑

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

	2,0	Laboratory	german
Literature			
siehe Vorlesung			

	2,0	Lecture	german
Literature			
Skript in deutscher und englischer Sprache C.Lüders, Mobilfunksysteme, Vogel-Verlag 2001 N.Geng, W.Wiesbeck, Planungsmethoden für die Mobilkommunikation, Springer-Verlag 1998 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	ET-NT-49	**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
2. Wave Propagation
3. Radio Transmission
4. Media Access
5. 3GPP Wireless Systems
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
- C. Lüders, Mobilfunksysteme, Vogel-Verlag 2001
- # J. Schiller, Mobilkommunikation, Addison-Wesley 2000
- N. Geng, W. Wiesbeck, Planungsmethoden für die Mobilkommunikation, Springer-Verlag 1998 #
- A. Molisch, Wireless Communications, Addison-Wesley 2005

Remark

This Master's module is also suitable for Bachelor students.

↑

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

	1,5	Exercise	english german
Literature			
siehe Vorlesung			

	2,5	Lecture	english german
Literature			
Skript C. Lüders, Mobilfunksysteme, Vogel-Verlag 2001 J. Schiller, Mobilkommunikation, Addison-Wesley 2000 N. Geng, W. Wiesbeck, Planungsmethoden für die Mobilkommunikation, Springer-Verlag 1998 A. Molisch, Wireless Communications, Addison-Wesley 2005			

Title	Speech Communication		
Number	2424500	**Module version**	
Shorttext	ET-NT-50	**Language**	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. Tim Fingscheidt
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 (90 min) (according to number of participants)		
Course achievement	Colloquium or laboratory protocol as proof of performance		

Contents

- Speech production
- Speech perception
- Linear prediction and speech modelling
- Speech coding
- Noise reduction
- Acoustic echo compensation

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

- Copies of lecture slides
- P.Vary u. R.Martin: Digital Speech Transmission, Wiley 2006

Remark

This module of the Master’s programme is also suited for Bachelor students.
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.

↑

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

	2,0	Lecture	german
Literature			
Kopien der Vorlesungsfolien P.Vary u. R.Martin: Digital Speech Transmission, Wiley 2006			

	2,0	Laboratory	german
Literature			
siehe Vorlesung			

Title	Microwave and Wireless Metrology		
Number	2424530	**Module version**	
Shorttext	ET-NT-53	**Language**	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 (30 min)		
Course achievement			

Contents

- Introduction to metrology
- Fundamentals of high-frequency technology
- Measurements in the time domain
- Spectrum analysis
- Vector network analysis
- Antenna measurement technology
- Channel measurements
- Protocol measurement technology

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

- Slides
- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde & Schwarz, 2004
- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde & Schwarz, 2007
- A.Molisch: Wireless Communications, Wiley, 2005

Remark

↑

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

	2,0	Lecture	german
Literature			
- Foliensammlung - C.Rauscher: Grundlagen der Spektrumanalyse, Rohde & Schwarz, 2004 - M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde & Schwarz, 2007 - A.Molisch: Wireless Communications, Wiley, 2005			

	2,0	Exercise	german
Literature			
- Foliensammlung - C.Rauscher: Grundlagen der Spektrumanalyse, Rohde & Schwarz, 2004 - M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde & Schwarz, 2007 - A.Molisch: Wireless Communications, Wiley, 2005			

Title	Advanced Seminar "Machine Learning"		
Number	2424600	Module version	
Shorttext	ET-IFR-42	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. 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.

↑

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

	2,0	Lecture	german
Literature			
Literatur wird im Seminar ausgegeben.			

	0,0	Project	german
Literature			
Literatur wird im Seminar ausgegeben.			

Title	Network Information Theory		
Number	2424650	**Module version**	
Shorttext	ET-NT-65	**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/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

- Review point-to-point channel capacity and coding theorem
- Strong typical sequences and their properties
- Multiple-Access Channel: Capacity region compared to TDMA/FDMA/SDMA/NOMA
- #Broadcast Channel: degraded BC capacity region, non-degraded BC achievable rate region and converse
- Interference Channel: very strong, strong, weak interference capacity region, medium interference achievable rate region and converse
- #Relay Channel: achievable schemes amplify-and-forward, decode-and-forward, compress-and-forward, estimate-and-forward #Generalization and application of elements to complex networks

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.
D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007.
T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006.
S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004.
R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.

↑

Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Network Information Theory	2,0	Lecture	english

Literature

A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011
D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007
T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006
S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004
R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008

Name of the course	SWS	Eventtype	Language
Network Information Theory	2,0	Exercise	english

Literature

- A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011. - D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007. - T.?M. Cover and J.?A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006. - S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004. - R.?W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.

Title	Spoken Language Processing		
Number	2424680	**Module version**	
Shorttext	ET-NT-68	**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

- Basics of speech production and perception
- Feature extraction
- Hidden Markov models
- Acoustic models and language models
- Automatic speech recognition
- Spoken language systems

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

- Lecture slides
- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001
- B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008
- A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004
- E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995
- G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003
- L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993
- K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990

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.

↑

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

	2,0	Lecture	english
Literature			
- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001 - B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008 - A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004 - E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995 - G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003 - L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993 - K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990			

	2,0	Seminar	english
Literature			
- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001 - B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008 - A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004 - E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995 - G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003 - L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993 - K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990			

Title	Pattern Recognition		
Number	2424690	**Module version**	
Shorttext	ET-NT-69	**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/ Type of examination	Oral exam 30 min. or written exam 90 min.		
Course achievement			

Contents

- Bayesian decision rule
- Quality metrics in pattern recognition
- Supervised learning with parametric distributions
- Supervised learning with non-parametric distributions, classification
- Linear discriminant functions, single-layer perceptron
- Support vector machines (SVMs)
- Multi-layer perceptron, neural networks (NNs)
- Deep learning
- Unsupervised learning, clustering methods

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.

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

- R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001
- C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006

Remark

Basic knowledge of statistics, such as acquired in the module "Probability Theory and Statistics", facilitates the understanding of the lecture.

↑

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

	2,0	Lecture	english german
Literature			
- R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001 - C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006			

	2,0	Seminar	english german
Literature			
- Vorlesungsfolien - R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001 - C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006			

Title	Optimization and Game Theory for Communications		
Number	2424700	**Module version**	
Shorttext	ET-IFR-42	**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/ Type of examination	Written exam (120) or oral exam (30 min), according to number of participants		
Course achievement			

Contents

Linear programming and resource allocation
Convex programming and power control
Global programming and interference networks
Non-cooperative games and distributed resource allocation
Coalitional games and ad-hoc networks

Objective qualification

The student can recognize, classify, and formulate optimization problems which typically occur in communications. They know diverse algorithms for solving the problems and are able to apply them successfully for programming problems related to current research in communications. The students know the basic mathematical tools in game theory and are able to apply them to model and solve cooperative and non-cooperative communication systems.

Literature

Bertsekas, Dimitri P. (2003). Convex Analysis and Optimization, Athena Scientific.
Boyd, S. and Vandenberghe, L. (2004). Convex Optimization, Cambridge University Press, (pdf).
Tuy, Hoang (2016). Convex Analysis and Global Optimization, Kluwer Academic.
M. J. Osborne und A. Rubinstein: A Course in Game Theory, The MIT Press, 1994.
D. Fudenberg und J. Tirole: Game Theory, The MIT Press, 1991. # M. J. Holler und G. Illing: Einführung in die Spieltheorie, Springer, 4. Auflage, 2000.
A. B. MacKenzie und L. A. DaSilva: Game Theory for Wireless Engineers (Synthesis Lectures on Communications), Morgan & Claypool Publishers, 2006.

↑

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

	2,0	Lecture	german
Literature			
? Bertsekas, Dimitri P. (2003). Convex Analysis and Optimization, Athena Scientific. ? Boyd, S. and Vandenberghe, L. (2004). Convex Optimization, Cambridge University Press, (pdf). ? Tuy, Hoang (2016). Convex Analysis and Global Optimization, Kluwer Academic. ? M.?J. Osborne und A. Rubinstein: A Course in Game Theory, The MIT Press, 1994. ? D. Fudenberg und J. Tirole: Game Theory, The MIT Press, 1991. ? M.?J. Holler und G. Illing: Einführung in die Spieltheorie, Springer, 4. Auflage, 2000. ? A.?B. MacKenzie und L.?A. DaSilva: Game Theory for Wireless Engineers (Synthesis Lectures on Communications), Morgan & Claypool Publishers, 2006.			

	1,0	Exercise	english
Literature			
? Bertsekas, Dimitri P. (2003). Convex Analysis and Optimization, Athena Scientific. ? Boyd, S. and Vandenberghe, L. (2004). Convex Optimization, Cambridge University Press, (pdf). ? Tuy, Hoang (2016). Convex Analysis and Global Optimization, Kluwer Academic. ? M.?J. Osborne und A. Rubinstein: A Course in Game Theory, The MIT Press, 1994. ? D. Fudenberg und J. Tirole: Game Theory, The MIT Press, 1991. ? M.?J. Holler und G. Illing: Einführung in die Spieltheorie, Springer, 4. Auflage, 2000. ? A.?B. MacKenzie und L.?A. DaSilva: Game Theory for Wireless Engineers (Synthesis Lectures on Communications), Morgan & Claypool Publishers, 2006.			

Title	Physical Layer Security		
Number	2424710	**Module version**	
Shorttext	ET-IFR-42	**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/ Type of examination	Written exam (120) or oral exam (30 min), according to number of participants		
Course achievement			

Contents

- 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.
- 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.
- Authentication: It covers how to identify the legitimate communication partners by channel testing/probing or by the use of the phyiscally unclonable functions.

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

- Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011.
- 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..
- T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006.
- A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011.
- R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.

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

	2,0	Lecture	english
Literature			
? Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011. ? 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.. ? T.?M. Cover and J.?A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006. ? A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011. ? R.?W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.			

	1,0	Exercise	english
Literature			
Literatur: ? Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011. ? 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.. ? T.?M. Cover and J.?A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006. ? A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011. ? R.?W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.			

Title	Information Theory		
Number	2424720	**Module version**	
Shorttext	ET-NT-72	**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/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

- Basics from probability theory
  - Event, probability, random variable, random vector, stochastic process, convergence of random series, convergence theorems
- Basics from information theory
  - Measures for discrete random varaibles: entropy, conditional entropy, relativ entropy, mutual information, conditional mutual information, inequalities
  - Measures for continous random variables: differential entropy, conditional differential entropy, relative entropy, mutual information, inequalities
  - Measure for random series
  - Typical sequences and asymptotic equipartition property
- Source and source coding
  - Definition and properties
  - Source coding for discrete memoryless sources (fixed and variable-length)
  - Selected source codes: Morse, Huffman, Shannon-Fano-Elias
- Data transmission and channel capacity
  - Discrete memoryless channel: channel coding theorem
  - Discrete memoryless channel with state: channel capacities
  - Gaussian channel: model and channel coding theorem
  - Bandlimited Gaussian channel, vector valued channels

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.
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

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
Information Theory	2,0	Lecture	german
Literature			
- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008. - 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			
Information Theory	1,0	Exercise	german
Literature			
- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008. - 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			

Title	Advanced Topics in Communications Theory		
Number	2424730	**Module version**	
Shorttext	ET-NT-73	**Language**	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	3 / 5,0	**Module owner**	Prof. Dr. Eduard Jorswieck
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

- Abstract stochastic modeling of communication channels
- Performance analysis of communication systems
- Coding and transmission via arbitrarily variable channels
- Multi-party networks and statistically dependent channels
- Bayesian Inference and Bayesian Statistics
- Fisher Information and Cramer Rao Bound
- Deep Neural Networks and global optimization
- Reinforcement Learning for optimization of complex communication systems

Objective qualification

In this module, students become familiar with current advanced topics in theoretical communications engineering. This includes current methods and tools from statistical signal processing and statistical and information theoretical modelling of communication systems (e.g. arbitrarily varying channels, copula) and the analysis and design of communication systems using learning algorithms (reinforcement learning, deep neural networks, etc.). The module enables students to deal with current research questions in theoretical communications engineering using modern solid methods.

Literature

Tse, David, and Viswanath, Pramod, Fundamentals of Wireless Communications, Cambridge University Press, 2005
Nelson, Rodger B., An Introduction to Copulas, Springer 2006.
Ahlswede, Rudolf, Probabilistic Methods and Distributed Information, Foundations in Signal Processing, Communications and Networking, Springer 2019.
D. Mckay, Information Theory, Inference, and Learning Algorithms, Cambridge University Press 2003.
Osvaldo Simeone, A Brief Introduction to Machine Learning for Engineers (Foundations and Trends(r) in Signal Processing).
Sutton, Richard S., and Andrew G. Barto. Reinforcement learning: An introduction. MIT press, 2018.
Box, George EP, and George C. Tiao. Bayesian inference in statistical analysis. Vol. 40. John Wiley & Sons, 2011.

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

	2,0	Lecture	english
Literature			
- Tse, David, and Viswanath, Pramod, Fundamentals of Wireless Communications, Cambridge University Press, 2005 - Nelson, Rodger B., An Introduction to Copulas, Springer 2006. - Ahlswede, Rudolf, Probabilistic Methods and Distributed Information, Foundations in Signal Processing, Communications and Networking, Springer 2019. - D. Mckay, Information Theory, Inference, and Learning Algorithms, Cambridge University Press 2003, - Osvaldo Simeone, A Brief Introduction to Machine Learning for Engineers (Foundations and Trends(r) in Signal Processing) - Sutton, Richard S., and Andrew G. Barto. Reinforcement learning: An introduction. MIT press, 2018. - Box, George EP, and George C. Tiao. Bayesian inference in statistical analysis. Vol. 40. John Wiley & Sons, 2011.			

	1,0	Exercise	english
Literature			
- Tse, David, and Viswanath, Pramod, Fundamentals of Wireless Communications, Cambridge University Press, 2005 - Nelson, Rodger B., An Introduction to Copulas, Springer 2006. - Ahlswede, Rudolf, Probabilistic Methods and Distributed Information, Foundations in Signal Processing, Communications and Networking, Springer 2019. - D. Mckay, Information Theory, Inference, and Learning Algorithms, Cambridge University Press 2003, - Osvaldo Simeone, A Brief Introduction to Machine Learning for Engineers (Foundations and Trends(r) in Signal Processing) - Sutton, Richard S., and Andrew G. Barto. Reinforcement learning: An introduction. MIT press, 2018. - Box, George EP, and George C. Tiao. Bayesian inference in statistical analysis. Vol. 40. John Wiley & Sons, 2011.			

Title	Physical Layer Security 2		
Number	2424740	**Module version**	
Shorttext	ET-NT-74	**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

- Review of information theory and physical layer security
- Sequential key distillation
- Privacy: differential privacy, stealth and covert communications, private information retrieval, wireless privacy
- Fading channels, ergodic and outage capacities, and artificial noise design
- Finite block length analysis and wiretap code implementations
- Active attacker

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.
S. Moser: Information Theory, https://moser-isi.ethz.ch/scripts.html#it
A. El Gamal and Y.-H. Kim, Network Information Theory, Cambridge University Press, 2011.
Research papers.

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

	2,0	Lecture	english
Literature			
? Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011. ? S. Moser: Information Theory, https://moser-isi.ethz.ch/scripts.html#it ? A. El Gamal and Y.-H. Kim, Network Information Theory, Cambridge University Press, 2011. ? Research papers			

	1,0	Exercise	english
Literature			
- Matthieu Bloch und João Barros: Physical-Layer Security - From Information Theory to Security Engineering, Cambridge University Press, 2011. - S. Moser: Information Theory, https://moser-isi.ethz.ch/scripts.html#it - A. El Gamal and Y.-H. Kim, Network Information Theory, Cambridge University Press, 2011. - Research papers			

Title	Multimedia Networking		
Number	4213170	**Module version**	V2
Shorttext	INF-KM-17	**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			
- R. Steinmetz: Multimedia Technologie. Springer-Verlag - S. Keshav: Computer Networking, Addision Wesley 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	INF-KM-39	**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/ Type of examination	1 graded work: Written exam (90 minutes) or oral exam (20 minutes) or Take-Home-Exam.		
Course achievement			
Contents			
- Internet protocols - IP - TCP - Routing methods - Newer protocols and methods			
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 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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

	4,0	Lecture/Exercise	english
Literature			
- 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			

	2,0	Exercise	english

Title	Mobile Communications		
Number	4213420	Module version	
Shorttext	INF	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/ Type of examination			
Course achievement			
Contents			
Objective qualification			
Literature			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	SWS	Eventtype	Language
Mobile Communications	4,0	Lecture/Exercise	english german
Literature			
J. Schiller: Mobilkommunikation - Techniken für das allgegenwärtige Internet, 2. Auflage, Addison-Wesley 2003			
	1,0	Exercise	english german

Title	Operating Systems		
Number	4225040	**Module version**	V3
Shorttext	Betriebssy	**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

- History of operating systems
- Process management
- Interprocess communication
- Memory management
- Input and output
- File systems

Objective qualification

- At the end of the course, students will have a good overview of the basic concepts of operating systems.
- In particular, they will have gained an in-depth understanding of processes and memory management.
- They will be able to identify the principles they have learned in real operating systems and assess the quality of their implementation.

Literature

- A. Tanenbaum:Modern Operating Systems, 2nd., Prentice-Hall,2001.
- W. Stallings: Operating Systems: International Version: Internals and Design Principles, 7th revised edition,Prentice Hall International, 2011.
- Silberschatz, Galvin, Gane:Operating System Concepts, 8th edition, John Wiley & Sons, 2011

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

Title	Machine Learning and Its Application in Communications Technology		
Number	2424000000	**Module version**	
Shorttext	ET-NT-0000	**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**	Prof. Dr. Eduard Jorswieck
Workload (h)	180		
Class attendance (h)	42	**Self studying (h)**	138
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement			

Contents

- Introduction of basic ideas of neural networks
- Introduction of the basic neural network architecture as well as loss function, gradient descent and optimizer for neural network training
- Setting up a development environment for machine learning with Python and Pytorch
- Hands-on experiment of defining and training of a simple deep neural network
- Introduction of advanced neural network architectures, including convolutional neural network, recurrent neural network, graph neural network and transformers. Understanding why they were invented and how they work
- Introduction of dedicated objective function for unsupervised learning in communications engineering
- Introduction of dedicated neural network architectures for unsupervised learning in communications engineering

Objective qualification

The students
- know the basics of neural network models
- understands the training process with massive data for supervised learning
- can generalize from supervised learning to unsupervised learning
- can implement and train the neural network model with Python and Pytorch for simple tasks
- understands how to consider domain knowledge of communications engineering in designing the neural network architecture and objective
- can optimize the training process if the outcome is not as expected

Literature

Y. C. Eldar, A. Goldsmith, D. Gündüz, H. V. Poor, Machine Learning and Wireless Communications, Cambridge University Press, 2022.
http://cs231n.stanford.edu/2019/

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

Machine learning and its application in communications technology	2,0	Lecture	german
Literature			
Y. C. Eldar, A. Goldsmith, D. Gündüz, H. V. Poor, Machine Learning and Wireless Communications, Cambridge University Press, 2022. http://cs231n.stanford.edu/2019/			

Machine learning and its application in communications technology	1,0	Exercise	german
Literature			
Y. C. Eldar, A. Goldsmith, D. Gündüz, H. V. Poor, Machine Learning and Wireless Communications, Cambridge University Press, 2022. http://cs231n.stanford.edu/2019/			

Title	Low power CMOS data converter circuit design		
Number	2420210	Module version	
Shorttext	ET-BST-21	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

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.

General introduction of data converters
1. Data converter application areas
Sensor interface, Communication (wireless/wireline)
2. Basic theory in data conversion
Sampling/Quantization, Performance metric (INL/DNL, SNDR, SFDR, ENOB, FoM)
3. Architectures and features of data converters
2-1. High resolution data converter (SAR, ##, VCO based)
2-2. High speed data converter (Flash, Pipeline)

Implementation of low-power and high-resolution CMOS integrated ADCs
4. Building blocks of ADC
Comparator, operational amplifier
5. SAR-ADC with charge redistribution.
3-1. Power reduction techniques
3-2. Resolution enhancement techniques (digital calibration etc.)
6. High resolution ## modulator
7. Time based (VCO based) ADC
8. Hybrid-ADC
9. Characterization of data converters

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	ET-IDA-01	**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

- Introduction to computer architecture
- Principles of computer architecture (control, pipelining, memory hierarchy)
- Microprocessors (RISC, ISC)
- Quantitative computer design
- Design of instruction sets

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 #
W. Stallings, Computer Organization & Architecture, 6. Edition, Prentice Hall, ISBN-13: 978-0-13-035119-7 #
Lecture notes

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	1,0	Exercise	german
	3,0	Lecture	german

Title	Media Technologies		
Number	2424160	**Module version**	
Shorttext	ET-NT-16	**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			
Aktuelle Systeme für die Elektronischen Medien: - H. Zander: Die aktuelle Audiotechnik, Drei-R-Verlag 1987 - E. Zwicker, R.Feldtkeller: Das Ohr als Nachrichtenempfänger, S. Hirzel Verlag, 2. Aufl., 1967 - U. Reimers: DVB-Digitale Fernsehtechnik: Datenkompression und Übertragung, Springer Verlag, 3. Auflage, 2008 - C. Biaesch-Wiebke: CD-Player und R-Dat-Recorder, Vogelbuch Verlag, 1992 - R. Mäusl: Fernsehtechnik, Hüthig Buch Verlag Heidelberg, 2. Aufl., 1995 - T. Lauterbach: Digital Audio Broadcasting, Franzis-Verlag, 1996 - D. Führer: ADSL, Hüthig Buch Verlag Heidelberg, 2000 Elektroaktustik: - Zollner/Zwicker: Elektroakustik, Springer Verlag - Kuttruff: Akustik - Eine Einführung, S. Hirzel Verlag Stuttgart Leipzig - Cremer/Möser: Technische Akustik, Springer Verlag - Ahnert: Beschallungstechnik, S. Hirzel Verlag Stuttgart Leipzig			
Remark			

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

	2,0	Lecture	german
Literature			
H.Zander: Die Digitale Audiotechnik, Drei-R-Verlag 1987 E.Zwicker, R.Feldtkeller: Das Ohr als Nachrichtenempfänger, S.Hirzel Verlag, 2.Aufl., 1967 U.Reimers: DVB - Digitales Fernsehen: Datenkompression und Übertragung, Springer Verlag, 3.Aufl., 2008 T.Coughlin: Digital Storage in Consumer Electronics, Elsevier-Verlag 2008			

	2,0	Lecture	german
Literature			
Zoller/Zwicker: Elektroakustik, Springer Verlag Kuttruff: Akustik - Eine Einführung, S.Hirzel Verlag Stuttgart Leipzig Cremer/Möser: Technische Akustik, Springer Verlag Ahnert: Beschallungstechnik, S.Hirzel Verlag Stuttgart Leipzig			

Title	Applied Quantum Computing: Basics and Devices		
Number	2413620	**Module version**	
Shorttext	ET-IHT-62	**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

- Basics of Quantum Mechanics
- From Bit to Qubit
- Quantum Circuits I
- Quantum Circuits II
- Entanglement and Teleportation
- Algorithms of Quantum Computing
- Quantum Hardware I
- Quantum Hardware II

Objective qualification

- The students can name the prerequisites for the realization of qubits as well as typical platforms and explain their significance.
- Students will be able to name the strengths and weaknesses of different hardware platforms in common application scenarios and weigh them against each other.
- 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.
- Students will be able to use an exemplary platform to explain how selected quantum gates can be realized.

Literature

[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019
[2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010
[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019
[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018
[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019

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

Applied Quantum Computing: Basics and Devices	2,0	Lecture	german
Literature			
[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019 [2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010 [3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019 [4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018 [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/ Type of examination	Written exam (60 min) or oral exam (30 min)		
Course achievement			

Contents

- Introduction to the basic concepts of quantum mechanics and quantum systems
- Introduction to quantum information theory
- Protocols for quantum computation and programming
- Introduction to quantum communication networks
- Capacity calculations for entanglement-assisted communication
- Introduction to communication with the help of quantum repeaters

Objective qualification

The students
- know the basics of quantum communication networks
- understand quantum information theory models
- can calculate rate limits of quantum information-theoretical networks
- understand simple protocols for quantum communication networks
- can simulate simple protocols for quantum communication networks
- can independently develop their own protocols for new models

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.
Bassoli, R., Boche, H., Deppe, C., Ferrara, R., Fitzek, F. H., Janssen, G., & Saeedinaeeni, S. (2023). *Quantenkommunikationsnetze*, Berlin/Heidelberg, Germany: Springer (2023).

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Quantum Communication Networks	2,0	Lecture	english
Quantum Communication Networks	1,0	Exercise	english

Title	VLSI-Lab		
Number	4211490	**Module version**	
Shorttext	INF-EIS-49	**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

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...

Objective qualification

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

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.

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
VLSI-Lab	4,0	Internship	english
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.			

Title			
Number	4211480	**Module version**	V2
Shorttext	INF-EIS-48	**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

- Introduction to VLSI Design
- Fundamentals of CMOS Transistors
- Fabrication and Layout of CMOS Integrated Circuits
- CMOS Circuits (Combinational and Sequential Logic Circuits)
- Design Methodologies
- Issues in Chip Design

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

- D. Harris, N. Weste: "CMOS VLSI Design.", Pearson Education, Inc (2010).
- H. Veendrick: "Nanometer CMOS ICs ", Springer, 2007
- Y. Taur, T. Ning: "Fundamentals of Modern VLSI Devices", Cambridge University Press, 1998
- J.M. Rabaey, A. P. Chandrakasan, and B. Nikoli#; “Digital Integrated Circuits: a Design Perspective”. Vol. 7. Upper Saddle River, NJ: Pearson Education, 2003.
- J. Uyemura: "CMOS Logic Circuit Design", Kluwer Academic Publishers, 1999
- K. Reifschneider: "CAE-gestützte IC-Entwurfsmethoden", Prentice Hall, 1998
- K. Itoh: "VLSI Memory Chip Design", Springer, 2001
- D. Jansen: "Handbuch der Electronic Design Automation", Carl Hanser Verlag, 2002
- R. J. Baker, H. W. Li, D. E. Byce: "CMOS Circuit Design. Layout, and Simulation", IEEE Press 1998
- R. Hunter, T. Johnson: "VHDL", Springer, 2007
- D. Perry: "VHDL", McGraw-Hill, 1998
- P. Ashenden: "The Designers Guide to VHDL", Morgan Kaufmann, 2002

Further references will be announced in the course.

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

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

- Introduction to the basic concepts of Post Shannon Theory
- Introduction to message identification
- Proof techniques for randomized and deterministic encoding
- Protocols with resources (feedback, sensing, common randomness)
- Methods for calculating upper bounds on capacity (resolvability)
- Coding methods for message identification

Objective qualification

The students
- know the basics of post Shannon theory
- understand randomized and deterministic message identification
- can calculate rate limits of Post Shannon models
- understand simple message identification protocols
- can create simple coding for message identification themselves
- can independently develop their own protocols for new models

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

Post Shannon Theory	2,0	Lecture	english
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			

Post Shannon Theory	1,0	Exercise	english
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			

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 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	Basic knowlesge of computer architectures and programming language C		
Expected performance/ Type of examination	1. Written exam (max 180 min) or oral exam (max 40 min) 2. Project work incl. written reports 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
2. Understanding of design components
3. Understanding of system-level design paradigms
4. HW/SW partitioning
5. Optimization methods
6. Performance analysis measures
7. Evaluation methods
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
[2] „Digitale Hardware/Software Systeme – Synthese und Optimierung“, J. Teich, Springer Verlag 1997, ISBN 3-540-62433-3

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
Hardware Software Codesign	3,0	Lecture	english
Literature			
[1] „Specification and Design of Embedded Systems”, D. Gajski, Prentice Hall 1994, ISBN 0-13-150731-1 [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
Literature			
[1] „Specification and Design of Embedded Systems”, D. Gajski, Prentice Hall 1994, ISBN 0-13-150731-1 [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	MB-IWF-91	**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

- Production technologies of micro and precision assembly #
- Typical components and assemblies used in micro and precision assembly and their development roadmaps # Established joining technologies in micro and precision assembly #
- Structured analysis of micro and precision assembly tasks #
- Typical kinematic structures of handling systems #
- Machine capability analysis for quantitative evaluation of the application-specific performance of assembly systems
- Kinematic error analysis for methodical analysis of the kinematically caused influences of structural and drive errors on the positioning accuracy of automated systems #
- Approaches to further increase the accuracy of assembly systems # Analysis techniques and methods for quality assurance

Objective qualification

Students... #
- are able to name and explain production processes and their elements in precision and micro production #
- 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) #
- are able to recognize and distinguish individual components of complex micro and precision assemblies and select suitable assembly technologies #
- 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 #
- are able to assess and differentiate between various kinematic structures and perform simple calculations with regard to their accuracy #
- 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 #

- 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 Prüfmethoden# #
- 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.

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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	ET-IDA-78	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/ Type of examination	oral exam (30 min)		
Course achievement			

Contents

• Cross Layer Design
• All-IP networks
• Integration of IP and Optical
• Inter-domain Routing
• Networks for Data Centers, Storage and Grid Computing
• Economics, Standards and Regulations in Telecommunications
• Applications of Networking in Energy, Automation and Health Care
• Research Literature, Papers and Surveys

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
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
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.

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

	1,0	Exercise	english
Literature			
Include latest research papers, tutorials and industrial standards			

	2,0	Lecture	english
Literature			
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 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/ Type of examination	Oral exam (30 min)		
Course achievement			

Contents

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.

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.

Objective qualification

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.

Literature

- Neuromorphic Computing for Computer Scientists
- Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601
- Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. https://www.nature.com/articles/s41928-023-01053-4
- C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 https://www.nature.com/articles/s43588-021-00184-y

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

Emerging Memory Technologies	2,0	Lecture	english

Literature

- T. Schenk et al., Memory technology – a primer for material scientists. Reports on Progress in Physics, 2020, 83, 086501. https://doi.org/10.1088/1361-6633/ab8f86
- W. Zhang et al., Designing crystallization in phase- change materials for universal memory and neuro-inspired computing. Nature Reviews Materials, 2019, 4, 150. https://doi.org/10.1038/s41578-018-0076-x
- D. Lencer et al., Design Rules for Phase-Change Materials in Data Storage Applications. Advanced Materials, 2011, 23 (18), 2030. https://doi.org/10.1002/adma.201004255
- S. W. Fong et al., Phase-Change Memory – Towards a Storage-Class Memory. IEEE Transactions on Electron Devices, 2017, 64 (11), 4374. https://doi.org/10.1109/TED.2017.2746342
- S. Yuasa et al., Materials for spin-transfer-torque magnetoresistive random-access memory. MRS Bulletin, 2018, 43, 352. https://doi.org/10.1557/mrs.2018.93
- S. Ikegawa et al., Magnetoresistive Random Access Memory: Present and Future. IEEE Transactions on Electron Devices, 2020, 67 (4), 1407. https://doi.org/10.1109/TED.2020.2965403
- H.-S. Philip Wong et al., Metal-Oxide RRAM. Proceedings of the IEEE, 2012, 100 (6), 1951. https://doi.org/10.1109/JPROC.2012.2190369
- M. N. Kozicki et al., Conductive bridging random access memory – materials, devices and applications. Semiconductor Science and Technology, 2016, 31 (11), 113001. https://doi.org/10.1088/0268-1242/31/11/113001

Emerging Memory Technologies	1,0	Exercise	english

Literature

- T. Schenk et al., Memory technology – a primer for material scientists. Reports on Progress in Physics, 2020, 83, 086501. https://doi.org/10.1088/1361-6633/ab8f86
- W. Zhang et al., Designing crystallization in phase- change materials for universal memory and neuro-inspired computing. Nature Reviews Materials, 2019, 4, 150. https://doi.org/10.1038/s41578-018-0076-x
- D. Lencer et al., Design Rules for Phase-Change Materials in Data Storage Applications. Advanced Materials, 2011, 23 (18), 2030. https://doi.org/10.1002/adma.201004255
- S. W. Fong et al., Phase-Change Memory – Towards a Storage-Class Memory. IEEE Transactions on Electron Devices, 2017, 64 (11), 4374. https://doi.org/10.1109/TED.2017.2746342
- S. Yuasa et al., Materials for spin-transfer-torque magnetoresistive random-access memory. MRS Bulletin, 2018, 43, 352. https://doi.org/10.1557/mrs.2018.93
- S. Ikegawa et al., Magnetoresistive Random Access Memory: Present and Future. IEEE Transactions on Electron Devices, 2020, 67 (4), 1407. https://doi.org/10.1109/TED.2020.2965403
- H.-S. Philip Wong et al., Metal-Oxide RRAM. Proceedings of the IEEE, 2012, 100 (6), 1951. https://doi.org/10.1109/JPROC.2012.2190369
- M. N. Kozicki et al., Conductive bridging random access memory – materials, devices and applications. Semiconductor Science and Technology, 2016, 31 (11), 113001. https://doi.org/10.1088/0268-1242/31/11/113001

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/ Type of examination	Oral exam (30 min)		
Course achievement			

Contents

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.

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.

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

- Neuromorphic Computing for Computer Scientists
- Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601
- Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. https://www.nature.com/articles/s41928-023-01053-4
- C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 https://www.nature.com/articles/s43588-021-00184-y

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

Neuromorphic Computing & Engineering	2,0	Lecture	english

Literature

- Neuromorphic Computing for Computer Scientists
- Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601
- Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. https://www.nature.com/articles/s41928-023-01053-4
- C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 https://www.nature.com/articles/s43588-021-00184-y

Neuromorphic Computing & Engineering	1,0	Exercise	english

Literature

- Neuromorphic Computing for Computer Scientists
- Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601
- Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. https://www.nature.com/articles/s41928-023-01053-4
- C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 https://www.nature.com/articles/s43588-021-00184-y

Title	Analog-to-Digital Converters		
Number	2420000030	**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. Thomas Kämpfe
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 (120 min)		
Course achievement			

Contents

- Introduction: information representation and communication; abstraction, categorization and symbolic representation; basic conversion algorithms; data converter application; tradeoffs among key parameters; ADC taxonomy.
- Dual-slope & successive approximation register (SAR) converters: dual slope principle & converter; SAR ADC operating principle; SAR implementation with a capacitive array; range extension with segmented array.
- Algorithmic & pipelined A/D converters: algorithmic conversion principle; sample & hold stage; pipe-lined converter; multiplying DAC; flash sub-ADC and n-bit MDAC; redundancy for correction of non-idealties, error correction.
- Performance metrics and non-linearity: ideal ADC; offset, gain error, differential and integral non-linearities; capacitor mismatch; impact of capacitor mismatch on SAR ADC's performance.
- Flash, folding an interpolating analog-to-digital converters: flash ADC principle, thermometer to binary coding, sparkle correction; limitations of flash converters; the folding principle, residue extraction; folding amplifiers; cascaded folding; interpolation for folding converters; cascaded folding and interpolation.
- Noise in analog-to-digital converters: types of noise; noise calculation in electronic circuit, kT/C-noise, sampled noise; noise analysis in switched-capacitor circuits; aperture time uncertainty and sampling jitter.
- Delta-sigma A/D-converters: linearity and resolution; from delta-modulation to delta-sigma modulation; first-oder delta-sigma modulation, circuit level implementation; clock-jitter & SNR in delta-sigma modulators; second-order delta-sigma modulation, higher-order modulation, design procedure for a single-loop modulator.
- Digital-to-analog converters: introduction; current scaling D/A converter, current steering DAC, calibration for improved performance.

Objective qualification

Students gain an in-depth understanding of the fundamental principles and operating concepts of analog-to-digital converters. They are familiar with key architectures such as SAR, pipeline, flash, and delta-sigma converters, and they understand their theoretical foundations, performance limits, and fields of application. Students are able to critically analyze different conversion schemes, calculate and interpret key performance metrics such as resolution, linearity, and noise, and evaluate them with respect to specific system requirements. They can model, simulate, and optimize the behavior of real converters under the influence of technological non-idealities. Based on this, students are capable of independently designing basic ADC circuits, assessing their performance, and making informed architectural choices for integrated mixed-signal systems. They develop the ability to analytically understand complex interrelations between architecture, technology, and system performance, and to make well-founded design decisions. Through the completion of practical and design-oriented tasks, they also strengthen their competencies in scientific reasoning, technical communication, and critical reflection.

Literature

- R. J. Baker, CMOS Circuit Design, Layout, and Simulation, second edition, Hoboken, NJ: J. Wiley Interscience, 2005.
- B. Murmann, Mixed-Signal Circuit Design, Springer, 2023.
- B. Murmann, ADC Performance Survey 1997–2024, Stanford University, online available: https://web.stanford.edu/~murmann/adcsurvey.html
- S. H. Lewis, H.-S. Lee, Analog-to-Digital Conversion, Springer, 2007

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Analog-to-Digital Converters	2,0	Lecture	english

Literature

R. J. Baker, CMOS Circuit Design, Layout, and Simulation, second edition, Hoboken, NJ: J. Wiley Interscience, 2005.

Name of the course	SWS	Eventtype	Language
Analog-to-Digital Converters	1,0	Exercise	english

Literature

R. J. Baker, CMOS Circuit Design, Layout, and Simulation, second edition, Hoboken, NJ: J. Wiley Interscience, 2005.

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

- System overview
- Jitter and phase noise
- Basic PLL architectures
- Analog integer PLL
- Digital integer PLL
- Fractional PLL
- Clock data recovery
- Delay locked loop
- Numerically controlled oscillator
- Software PLL

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
Behzad Razavi “Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level”, Cambridge University Press, 2020

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

Phase-Locked Loops and Frequency Synthesis	2,0	Lecture	english
Literature			
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
Literature			
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			

<table>
<tr><td>Title</td><td colspan="3">Verification, Validation and Testing of ASIC Designs</td></tr>
<tr><td>Number</td><td>4211500</td><td>Module version</td><td></td></tr>
<tr><td>Shorttext</td><td>INF-EIS-50</td><td>Language</td><td>english</td></tr>
<tr><td>Frequency of offer</td><td>only in the summer term</td><td>Teaching unit</td><td></td></tr>
<tr><td>Module duration</td><td>1</td><td>Institution</td><td>Institut für Theoretische Informatik</td></tr>
<tr><td>Hours per Week / ECTS</td><td>4 / 5,0</td><td>Module owner</td><td>Prof. Dr. Guillermo Payá Vayá</td></tr>
<tr><td>Workload (h)</td><td colspan="3">150</td></tr>
<tr><td>Class attendance (h)</td><td>56</td><td>Self studying (h)</td><td>94</td></tr>
<tr><td>Compulsory requirements</td><td colspan="3"></td></tr>
<tr><td>Expected performance/ Type of examination</td><td colspan="3">graded work (examination): oral exam (30 minutes)</td></tr>
<tr><td>Course achievement</td><td colspan="3"></td></tr>
<tr><td colspan="4">Contents</td></tr>
<tr><td colspan="4">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</td></tr>
<tr><td colspan="4">Objective qualification</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td colspan="4">Literature</td></tr>
<tr><td colspan="4">- 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.</td></tr>
</table>

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
Verification, Validation and Testing of ASIC Designs	4,0	Lecture/Exercise	english
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" Weitere Referenzen werden in der Veranstaltung bekannt gegeben.			

Title	Memory Systems		
Number	4211460	Module version	V2
Shorttext	INF-EIS-46	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)
2. Overview on Memory Technology
2.1 Volatile Memories: SRAM, DRAM
2.2 Non-volatile Memories: ROM, Flash Memory, F-RAM, MRAM,...
3. Main Memory: Interfaces, Commands, and Controllers
4. Memory Cache
5. Processing-in-Memory (PIM) / New Data Processing
5.1 Using traditional and 3D-Stacked memories
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
• Hennessy and Patterson (2017): "Computer Architecture. A Quantitative Approach", 6th Edition, Morgan Kaufmann
• Jacob, Ng, and Wang (2008): "Memory Systems: Cache, DRAM, Disk", Morgan Kaufmann "

Further references will be announced in the course.

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Memory Systems	2,0	Lecture	english

Literature

- Balasubramonian (2019): "Innovations in the Memory Systems", Morgen & Claypool Publishers
- Hennessy and Patterson (2017): "Computer Architecture. A Quantitative Approach", 6th Edition, Morgan Kaufmann
- Jacob, Ng, and Wang (2008): "Memory Systems: Cache, DRAM, Disk", Morgan Kaufmann "

Further references will be announced in the course.

Memory Systems	2,0	Exercise	english

Title	Advanced FPGA-Design		
Number	4211510	Module version	V2
Shorttext	INF-EIS-51	Language	english german
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/ 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
2. FPGA Basic Architecture (incl. DSP blocks, embedded memories, soft and hard processors) (Review)
3. Additional Architectural Elements of FPGAs (Boundary scan, I/O cells (PLLs), MIG, transceivers, analog-to-digital converters, ...)
4. FPGA Memory Technologies (SRAM, EPROM, Flash, Anti-Fuse, MRAM)
5. High-Performance Circuit Design on FPGAs
6. Dynamic and Partial Reconfiguration Mechanisms (incl. Space-Time FPGAs)
7. Design Tools for FPGAs (incl. VTR)
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

- 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

Further references will be announced in the course

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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

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

Title	Control of Electrical Devices		
Number	2412680	**Module version**	
Shorttext	ET-IFR-68	**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, asychronous 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 - W. Leonhard: Control of elektrical Drives, Springer-Verlag, ISBN: 978-3540418207			
Remark			
Requirements: Lecture „Fundamentals of control technologies“			

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

Title	Applied Power Electronics		
Number	2414230	**Module version**	
Shorttext	ET-IMAB-23	**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

- Power electronics and electromagnetic compatibility (EMC)
- EMC guidelines and filter circuits
- Power Factor Correction (PFC)
- Resonant power converters
- Quasi-resonant circuits
- Multi-level converters

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
Applikationshandbuch Leistungshalbleiter, Semikron, ISLE-Verlag

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

	2,0	Lecture	german
Literature			
- Skript - DIN 41750: "Begriffe für Stromrichter", Beuth Verlag GmbH, 1984 - Jötten, R.: "Leistungselektronik", Vieweg Verlag, Braunschweig, 1977 - Heumann/Stumpe: "Thyristoren", Teubner Verlag, Stuttgart, 1970			

	2,0	Exercise	german

Title	A.C. Drive Systems and their Computer Simualtion		
Number	2414250	**Module version**	
Shorttext	ET-IMAB-25	**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

- Overview of converter-fed drive systems: energy supply, power semiconductors, motors, loads
- Modelling and simulation of the components in the drive system
- Application of space vector theory
- Hardware in the loop methods
- Simulation of electromagnetic converters, numerical simulation programmes
- Practical simulation exercises with various simulation tools

Objective qualification

After completing the module, students can select drive systems and simulate simple electromechanical systems.

Literature

Schröder D., Elektrische Antriebe - Grundlagen, Springer 2009
Seefried / Müller, Frequenzgesteuerte Drehstrom-Asynchronantriebe, Verlag Technik Berlin, 1992

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

	3,0	Lecture	german
Literature			
R. Fischer, Elektrische Maschinen, Hanser, ISBN-13: 9783446452183 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	ET-HTEE-55	**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

- Discussion of power system overvoltages
- Calculation of electric fields
- Statistical analysis of ionization and breakdown phenomena
- Calculation of the breakdown of gases (SF6), liquids (insulating oil), solids, and composite materials, as well as the breakdown characteristics of long air gaps
- 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
- Examination of contemporary practices in insulation coordination in association with the International Electrotechnical Commission (IEC) definition and the latest standards.

Objective qualification

The students have fundamental knowledge of Power Systems and special or in-depth expertise for High-Voltage Systems
Engineering.
They learn methods with the help of discipline experiments and simulations and interpret / evaluate texts and data from
Power Systems.
They are able to make scientifically sound judgments within the scope of High-Voltage and formulate research problems.
The students are able to select an adequate level of abstraction for a given research problem and work on that level.
They can assess the scientific value of High-Voltage research and can formulate development or application problems.
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.
They reflect critically on their own way of thinking, their decisions and actions and are able to think logically (recognize

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

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Related courses

Rules for the choice of courses

Compulsory attendance

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

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

	2,0	Exercise	english

Title	Electrical Systems and Grids		
Number	2423560	**Module version**	
Shorttext	ET-HTEE-56	**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/ Type of examination	oral exam (30 min) or written exam (120 min)		
Course achievement			

Contents

Line and network types
Equivalent circuits of the networks
Electrical characteristics of the equipment
Calculation of lines and networks
Network control
Short circuit and load flow calculation
Stability
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

↑

Related courses

Rules for the choice of courses

Compulsory attendance

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

- Nodes in the network, all voltage levels
- Basics of networks: Grounding system, Error types
- Isolation Coordination
- Thermal and mechanical stress
- Protection Systems
- Switching operations: Component network interface
- Switches: AC and DC extinguishing principle
- Fundamentals of Plasma Technology
- Vacuum switch
- Gas switch
- DC Voltage Switches
- Transformer
- Structure of switchgear and basic circuits used

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 insiqhts 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-Leistungsbauelemente: 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").

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Introduction to power grid technology	2,0	Lecture	german

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-Leistungsbauelemente: 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

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-Leistungsbauelemente: 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	ET-IFR-39	**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
- J. Lunze: Regelungstechnik 2, Springer-Verlag, ISBN: 978-3540784623
- O. Föllinger: Nichtlineare Regelungen 1 & 2, Hüthig-Verlag, ISBN: 978-3486245271 & 978-3486225037
- W. Leonhard: Einführung in die Regelungstechnik, Vieweg-Verlag, ISBN: 978-3528535841

Remark

Prerequisite: Lecture "Fundamentals of Control Engineering"

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
	2,0	Exercise	german
	2,0	Lecture	german

Title	Control of Electric Power Systems		
Number	2412450	**Module version**	
Shorttext	ET-IFR-45	**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:

- Introduction to grid control
- Power transmission in the three-phase grid
- Frequency and voltage control of synchronous generators in power plants
- Simulation of conventional power plants in Matlab/Simulink (exercise)
- Frequency and voltage control in electrical grids
- Basics of the control of power converters
- Grid-following and grid-forming converter control
- Simulation of converter-based renewable energies in Matlab/Simulink (exercise)
- Implementation of grid functions (P(f), Q(U), FRT, ...) in the power converters
- Fundamentals of the control of DC systems, especially battery storage systems
- Weekly implementation of the learned controls in Matlab/Simulink (simulation software)

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

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

Title	Control of Electrical Devices		
Number	2412680	**Module version**	
Shorttext	ET-IFR-68	**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, asychronous 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
- W. Leonhard: Control of elektrical Drives, Springer-Verlag, ISBN: 978-3540418207

Remark

Requirements: Lecture „Fundamentals of control technologies“

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

Title	Electrical Machines and Drives		
Number	2414180	**Module version**	
Shorttext	ET-IMAB-18	**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	Written exam (120 minutes) or oral exam (30 minutes)		
Course achievement			

Contents

- Speed and torque control of direct current and three-phase drives with power electronic control circuits
- Operating behaviour of permanent magnet and salient pole synchronous machines
- Modelling of electrical machines and drives
- Design and control of magnetic bearings

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
Schröder D., Elektrische Antriebe Grundlagen, Springer
Hofmann W., Elektrische Maschinen, Pearson
Hagl, Elektrische Antriebstechnik, Hanser

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Exercise	german
Literature			
Skript			

	2,0	Lecture	german
Literature			
Skript, H.O. Seinsch, Ausgleichsvorgänge bei elektrischen Antrieben, Teubner Verlag, Stuttgart			

Title	Basic Circuits of Power Electronics		
Number	2414190	**Module version**	
Shorttext	ET-IMAB-19	**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

- Components of power electronics
- Simulation of power electronics
- Dimensioning of chokes and transformers
- Functionality and design of DC converters and switching power supplies
- Control and protective circuitry of power semiconductors
- Power loss and cooling of power semiconductors

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

	2,0	Exercise	german
	2,0	Lecture	german

Literature

Jürgen Meins: "Elektromechanik", B.G. Teubner Verlag 1997 Schaltnetzteile und ihre Peripherie, Ulrich Schlienz, Vieweg-Verlag

Title	Design of Electrical Machines		
Number	2414200	**Module version**	
Shorttext	ET-IMAB-20	**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/ Type of examination	Written exam (120 min) or oral exam (30 min)		
Course achievement			

Contents

- Force and torque buildup in electrical machines
- Winding design of rotating field machines
- Winding factor calculation
- Fundamentals of thermal modelling of electrical machines
- Cooling mechanisms
- Finite element methods for electromagnetic machine design
- Analytical design of electrical machines
- Motor topologies for automotive and aviation applications

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
G. Müller, B. Ponick: Theorie elektrischer Maschinen, VCH
H.O. Seinsch, Ausgleichsvorgänge bei elektrischen Antrieben, Teubner Verlag, Stuttgart

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

	2,0	Lecture	german
Literature			
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	ET-IMAB-22	**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/ 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
Reif, Noreikat, Bergeest, Kraftfahrzeug-Hybridantriebe, Springer

↑

Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
	1,0	Lecture	german

	1,0	Lecture	german
	2,0	Exercise	german

Title	Applied Power Electronics		
Number	2414230	**Module version**	
Shorttext	ET-IMAB-23	**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

- Power electronics and electromagnetic compatibility (EMC)
- EMC guidelines and filter circuits
- Power Factor Correction (PFC)
- Resonant power converters
- Quasi-resonant circuits
- Multi-level converters

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
Applikationshandbuch Leistungshalbleiter, Semikron, ISLE-Verlag

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

	2,0	Lecture	german
Literature			
- Skript - DIN 41750: "Begriffe für Stromrichter", Beuth Verlag GmbH, 1984 - Jötten, R.: "Leistungselektronik", Vieweg Verlag, Braunschweig, 1977 - Heumann/Stumpe: "Thyristoren", Teubner Verlag, Stuttgart, 1970			

	2,0	Exercise	german

Title	A.C. Drive Systems and their Computer Simualtion		
Number	2414250	**Module version**	
Shorttext	ET-IMAB-25	**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			
- Overview of converter-fed drive systems: energy supply, power semiconductors, motors, loads - Modelling and simulation of the components in the drive system - Application of space vector theory - Hardware in the loop methods - Simulation of electromagnetic converters, numerical simulation programmes - Practical simulation exercises with various simulation tools			
Objective qualification			
After completing the module, students can select drive systems and simulate simple electromechanical systems.			
Literature			
Schröder D., Elektrische Antriebe - Grundlagen, Springer 2009 Seefried / Müller, Frequenzgesteuerte Drehstrom-Asynchronantriebe, Verlag Technik Berlin, 1992			

↑

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

	3,0	Lecture	german
Literature			
R. Fischer, Elektrische Maschinen, Hanser, ISBN-13: 9783446452183 Binder A.: Elektrische Maschinen und Antriebe, Springer ISBN 978-3-540-71850-5			

	2,0	Exercise	german

Title	Advanced Power Electronics		
Number	2414300	**Module version**	
Shorttext	ET-IMAB-30	**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

- Requirements analysis
- DC converters without and with transformer, bidirectional concepts
- Multi-parallel converters
- Single-phase and three-phase inverters, design variants, modulation types, bidirectionality
- Active and passive power electronic components: electrical and thermal properties, measurement technology for characterization, reliability, service life

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.
Josef Lutz: Halbleiter-Leistungsbauelemente. Springer Verlag.

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

	2,0	Lecture	german
Literature			
Dierk Schröder: Leistungselektronische Schaltungen. Springer Verlag. Josef Lutz: Halbleiter-Leistungsbauelemente. Springer Verlag.			

	2,0	Exercise	german

Title	Electromagnetic Compatibility		
Number	2419120	**Module version**	
Shorttext	ET-IEMV-12	**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
Hours per Week / ECTS	3 / 5,0	**Module owner**	Dr. Harald Spieker
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

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices #
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference #
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection #
- Legal basis, product liability, standardization #
- EMC test engineering #
- Electromagnetic compatibility of biological systems

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

- Lecture notes
- Joachim Franz, EMV – Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

↑

Related courses

Rules for the choice of courses

Either this module or "Electromagnetic Compatibility with Seminar" can be selected.

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Electromagnetic Compatibility	2,0	Lecture	german
Electromagnetic Compatibility	1,0	Exercise	german

Title	Electromagnetic Compatibility with Seminar		
Number	2419130	**Module version**	
Shorttext	ET-IEMV-13	**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
Hours per Week / ECTS	5 / 6,0	**Module owner**	
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

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection
- Legal basis, product liability, standardization
- EMC test engineering
- Electromagnetic compatibility of biological systems
- Current EMC issues presented in seminar talks

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

- continuously updated script handout
- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

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Related courses

Rules for the choice of courses

You can either choose Electromagnetic Compatibility with Seminar **or** Electromagnetic Compatibility (without seminar). The seminar can also be attened in the summer semester after having attended the EMC lecture.

Compulsory attendance

Name of the course	SWS	Eventtype	Language
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	ET-HTEE-36	**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

- Calculation of electric fields in insulation systems
- Description of the origin and calculation of the propagation of overvoltages in networks
- Overview of protective measures against overvoltages
- Introduction to the electrical strength theory of insulation systems
- Introduction to the statistical calculation of breakdown processes
- Determination of the electrical strength of insulating gases
- Description of vacuum breakdown processes
- Determination of the electrical strength of insulation systems with solid insulating material

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
Elektrische Energieversorgung, K. Heuck, Vieweg

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**

	1,0	Exercise	german
	3,0	Lecture	german

Title	System Technology for Photovoltaic		
Number	2423380	**Module version**	
Shorttext	ET-HTEE-38	**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/ 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
2. system configurations
3. inverter topologies
4. functions of the inverters
5. other components of PV system technology
6. grid integration of PV systems
7. off-grid systems
8. grid-connected PV systems with storage
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
Photovoltaik für Profis, Falk Antony et. al., Verlag Solarpraxis, ISBN 978-3-934595-38-5
Lecture notes

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

	2,0	Lecture	german
Literature			
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
Literature			
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	ET-HTEE-43	**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/ Type of examination	oral exam (30 min)		
Course achievement			

Contents

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.
are also considered.
0 . Repetitorium: Fundamentals of electrical engineering and electrical power engineering for electric railways
1 Introduction: Classification of railway vehicles and electric road bus systems
2. national and international stationary traction current systems, DC and AC
3. electric drives
- Historical development of drive topologies
- Inverter systems
- Drive control
- Traction motors and mechanical drive configurations
- Internal combustion vehicles/power transmission types
4. auxiliary systems
- Heating, air conditioning and ventilation
- Batteries, local grid feeds
- Auxiliary converter topologies
5. signalling and security systems
- Overview of the most important systems used in Europe
- On-board equipment
6. control technology on railway vehicles
- Tasks: Control and diagnostics
- Train and vehicle buses and their components
7. passenger information and multimedia
8 Vehicles operated
TRAXX, EuroSprinter, ICE 3, LIREX, ET 423, regional urban railway Regio CITADIS for Kassel, LINT
9. future developments
Fuel cell, electronic transformer, gearless direct drive, hybrid vehicles, contactless energy transmission energy transmission
10. electric road bus systems (trolleybus, battery bus with inductive/conductive charging)

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

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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	ET-HTEE-42	**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/ Type of examination	Written exam (120 min) or oral exam (30 min)		
Course achievement			

Contents

1. energy economics
2. energy policy
3. laws and subsidy systems
4. markets (electricity market 2.0, balancing power market)
5. direct marketing / balancing group management
6. virtual power plant
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 Tim Wawer: Elektrizitätswirtschaft

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Related courses

Rules for the choice of courses

Compulsory attendance

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	ET-HTEE-42	**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

-Introduction to HVDC Systems
-Thyristors
- Six Pulse Diode and Thyristor Converter
- HVDC Rectifier Station Modelling, Control and Synchronization with AC System HVDC Inverter Station Modeling and Control
- HVDC System V-I Diagrams and Operation Modes
- HVDC Phasor Modeling and Interaction with AC System
- HVDC Operation with Weak AC Systems
- VSC-HVDC Applications, Topologies, Performance, and Cost Comparison with LCC
- IGBT Switches and VSC Converter Losses
- Single Phase and Three Phase Two-Level VSC Converters
- Two Level PWM VSC Converter
- VSC-HVDC Applications for AC Grid
- HVDC Grids

Objective qualification

Upon completion of this course, the students shall understand:
- The main differences between AC and DC transmission
- The main components of HVDC systems
- The operation principles of different power semiconductor devices

After completing the course, the candidate should be able to:
-Establish and modeling of AC and DC sources
-Modeling of half wave and full wave rectifiers
-Modeling of DC-DC buck converter
-Modeling of DC-DC boost converter
-Modeling of single phase thyristor converter
-Modeling of three phase thyristor converter
-Modeling of pulse width modulation (PWM)
-Modeling of HVDC link

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

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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	ET-IFR-39	**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

- Calculation and design of DC-networks
- Operation of DC-networks
- Fault detection and localization
- Plant engineering
- Components for power generation, distribution and storage
- Industrial networks, isolated networks, on-board networks

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)
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)

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

	2,0	Lecture	german
Literature			
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
Literature			
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 calculation of DC systems		
Number	2423530	**Module version**	
Shorttext	ET-IFR-39	**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	oral examination, 30 minutes or written exam, 120 minutes		
Course achievement			

Contents

- Charging infrastructure
- Double layer capacitor
- Hydrogen technology
- Storage parameters, system design
- Storage technologies
- Battery storage, ageing and diagnostics, recycling

Objective qualification

After successful completion of the module, students have a basic knowledge of the structure and function of storage systems.
They are informed about current and future developments in storage systems and can formulate existing challenges.
Students learn practical skills through excursions and exercises.

Literature

Zapf, M.: Stromspeicher und Power-to-Gas im deutschen Energiesystem. Springer Vieweg, 2017
Sterner, M.; Stadler, I.: Energiespeicher # Bedarf, Technologien, Integration. Springer Vieweg, 2014
Kurzweil, P.; Dietlmeier, O. K.: Elektrochemische Speicher - Superkondensatoren, Batterien, Elektrolyse-Wasserstoff, Rechtliche Grundlagen, Springer Vieweg, 2015
Korthauer, R. (Hrsg.): Handbuch Lithium-Ionen-Batterien, Springer Vieweg, 2013

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

	2,0	Lecture	german
Literature			
Zapf, M.: Stromspeicher und Power-to-Gas im deutschen Energiesystem. Springer Vieweg, 2017 Sterner, M.; Stadler, I.: Energiespeicher ? Bedarf, Technologien, Integration. Springer Vieweg, 2014 Kurzweil, P.; Dietlmeier, O. K.: Elektrochemische Speicher - Superkondensatoren, Batterien, Elektrolyse-Wasserstoff, Rechtliche Grundlagen, Springer Vieweg, 2015 Korthauer, R. (Hrsg.): Handbuch Lithium-Ionen-Batterien, Springer Vieweg, 2013			

	2,0	Exercise	german

Title	Electric Power Systems Engineering		
Number	2423550	**Module version**	
Shorttext	ET-HTEE-55	**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

- Discussion of power system overvoltages
- Calculation of electric fields
- Statistical analysis of ionization and breakdown phenomena
- Calculation of the breakdown of gases (SF6), liquids (insulating oil), solids, and composite materials, as well as the breakdown characteristics of long air gaps
- 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
- Examination of contemporary practices in insulation coordination in association with the International Electrotechnical Commission (IEC) definition and the latest standards.

Objective qualification

The students have fundamental knowledge of Power Systems and special or in-depth expertise for High-Voltage Systems
Engineering.
They learn methods with the help of discipline experiments and simulations and interpret / evaluate texts and data from
Power Systems.
They are able to make scientifically sound judgments within the scope of High-Voltage and formulate research problems.
The students are able to select an adequate level of abstraction for a given research problem and work on that level.
They can assess the scientific value of High-Voltage research and can formulate development or application problems.
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.
They reflect critically on their own way of thinking, their decisions and actions and are able to think logically (recognize

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

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Related courses

Rules for the choice of courses

Compulsory attendance

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

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

Name of the course	SWS	Eventtype	Language
	2,0	Exercise	english

Title	Electrical Systems and Grids		
Number	2423560	**Module version**	
Shorttext	ET-HTEE-56	**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/ Type of examination	oral exam (30 min) or written exam (120 min)		
Course achievement			

Contents

Line and network types
Equivalent circuits of the networks
Electrical characteristics of the equipment
Calculation of lines and networks
Network control
Short circuit and load flow calculation
Stability
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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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**

	1,0	Exercise	german
	2,0	Lecture	german

Title	High-Voltage Test- and Measurement Systems		
Number	2423570	**Module version**	
Shorttext	ET-HTEE-57	**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 exam (30 min) or written exam (120 min)		
Course achievement			
Contents			
Design of High-Voltage Components Test Philosophy and Design of Test Concepts for High-Voltage Test Facilities High-Voltage Generation High-Voltage Measurement High-Current Generation High Current Measurement			
Objective qualification			
Fundamental Knowledge of High-Voltage and High-Current Tests Fundamental Analysis of High-Voltage and High-Current Test and Measurement Circuits Quality Assessment, Evaluation and Documentation of Test Performance for High-Voltage Components			
Literature			
High-Voltage Test and Measuring Techniques, Wolfgang Hauschild, Eberhard Lemke, Springer, 2014			

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

	2,0	Exercise	english
	2,0	Lecture	english

Title	Numerical Methods		
Number	2423590	Module version	
Shorttext	ET-HTEE-59	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	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

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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	ET-HTEE-60	**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/ Type of examination	oral exam (30 min) or written exam (90 min)		
Course achievement			

Contents

1. Development of Energy Supply and Climate Targets
2. Conventional Power Plants
3. Renewable Energies
4. Novel generation systems
5. Power-to-X and Sector Coupling (Transport, Heat)
6. Storage (Battery, Hydrogen)
7. Island Grids
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.
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.

↑

Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	2,0	Lecture	german
Literature			
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	ET-HTEE-42	**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	Written exam (120 minutes) or oral exam (30 min)		
Course achievement			

Contents

- High-Voltage Technologies
- Smart Grids
- High-Voltage Direct Current Transmission
- High-Temperature Superconductors

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
Elektroenergiesysteme, A. Schwab, Springerverlag
Elektrische Energieversorgung, K. Heuck, Vieweg
Grundkurs Leistungselektronik, J. Specovius, Vieweg+Teubner Verlag
Supraleitung, W. Buckel, VCH

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Related courses
Rules for the choice of courses
Bachelor's module
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
	2,0	Exercise	german
	2,0	Lecture	german

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

Practical experiments in the areas of:
- Formation and post-mortem analysis
- Electrochemical characterizations
- Pressure analysis
- Simulation and modeling

The practical experiments include preparation, experimental work, colloquium and written elaboration. This knowledge will be deepened during the seminar.

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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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
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	ET-HTEE-30	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/ Type of examination	Written exam (120 min)		
Course achievement			

Contents

- Electrical Grid and Grid structures
- Basic terms, energy history, future
- Cable and overhead line
- Transformer
- Substations and Control rooms
- Grid safety & security
- Grid planning, calculation and AI
- Grid financing and grid fees
- Innovative grid operation using the example of medium and low voltage grids
- Active power management in distribution grids

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
Elektrische Energieversorgung – Heuck, Dettmann, Schulz – SpringerVieweg
Taschenbuch der elektrischen Energietechnik – Schufft – Hanser
Elektrische Anlagentechnik – Knies, Schierack – Hanser
Elektroenergiesysteme – Schwab – Springer

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
	3,0	Lecture	german

Literature

Elektrische Energieverteilung; Flosdorff, Hilgarth; Vieweg + Teubner Elektrische Energieversorgung; Heuck, Dettmann, Schulz; SpringerVieweg Taschenbuch der elektrischen Energietechnik; Schufft; Hanser Elektrische Anlagentechnik; Knies, Schierack; Hanser Elektroenergiesysteme; Schwab; Springer

	1,0	Exercise	german

Literature

Elektrische Energieverteilung; Flosdorff, Hilgarth; Vieweg + Teubner Elektrische Energieversorgung; Heuck, Dettmann, Schulz; SpringerVieweg Taschenbuch der elektrischen Energietechnik; Schufft; Hanser Elektrische Anlagentechnik; Knies, Schierack; Hanser Elektroenergiesysteme; Schwab; Springer

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

- Nodes in the network, all voltage levels
- Basics of networks: Grounding system, Error types
- Isolation Coordination
- Thermal and mechanical stress
- Protection Systems
- Switching operations: Component network interface
- Switches: AC and DC extinguishing principle
- Fundamentals of Plasma Technology
- Vacuum switch
- Gas switch
- DC Voltage Switches
- Transformer
- Structure of switchgear and basic circuits used

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 insiqhts 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-Leistungsbauelemente: 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").

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

Introduction to power grid technology	2,0	Lecture	german
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-Leistungsbauelemente: 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
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-Leistungsbauelemente: 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: Photonics and Quantum Technologies - Compulsory Elective Modules

Title	Nano- and Bioelectronic System		
Number	2413560	**Module version**	
Shorttext	ET-IHT-56	**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
growth, nanostructuring and characterization processes and tools (lithography, microscopy, raster probe technique, spectroscopy, nanotubes, nanowires, nanoparticles, hybrid nanostructures
bio-organic functionalization of surfaces (Langmuir-Blodgett, self-assembled monolayers on metals and semiconductors)
semiconductor nano- and biosensors based on different inorganic and organic nanomaterials
hybrid nanostructures for optoelectronics

Objective qualification

After completion of the module Nano- and Bioelectronic Systems, the students possess
- 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)
- 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
"Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer, 2nd. Ed. (2006): ISBN-13: 978-3540298557

Remark

primarily master module

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

	2,0	Lecture	german
Literature			
"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
Literature			
"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	ET-IHF-29	**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/ Type of examination	Written exam (90 min) or oral exam (30 min) or presentation		
Course achievement			

Contents

- Propagation of electromagnetic waves in free space and in guiding structures
- Refraction, reflexion, total reflexion at dielectric interfaces
- Optical guiding in film and strip waveguides, mechanisms of losses
- Optical modes and theoretical description
- field distribution in step and gradient profiles, analogy to quantum mechanics
- Periodic structures to distributed feedback: DFB, DBR
- Electrooptical interaction, directional couplers

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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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	Nonlinear Photonics		
Number	2415470	**Module version**	
Shorttext	ET-IHF-47	**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
- Basics of linear optics - 2nd order nonlinear optical effects - 3rd order nonlinear optical effects - Nonlinear scattering - Optical telecommunications - Nonlinear effects in optical fibers - Suppression of nonlinear effects - Applications of nonlinear effects
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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

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

Title	Analog Integrated Circuits		
Number	2420150	**Module version**	
Shorttext	ET-BST-15	**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

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.

The lecture is divided into the following chapters:
- High frequency amplifier circuits
- Simulation of electronic noise
- Low-noise input amplifiers in CMOS
- Mixer circuits
- Phase-locked loops (PLLs)
- Voltage-controlled oscillators

Objective qualification

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).

Literature

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

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Related courses			
Rules for the choice of courses			
Prerequisite for this module: Circuit Design (ST)			
Compulsory attendance			

Name of the course	SWS	Eventtype	Language
Analog Integrated Circuits (2013)	1,0	Exercise	english
Analog Integrated Circuits (2013)	2,0	Lecture	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/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

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:

- Physical principles of LEDs. Band gap engineering in LEDs.
- Semiconductor materials for optoelectronics
- Relationship between material properties and LED properties
- Manufacturing processes
- Efficiency considerations
- Front-end and back-end processing
- Application examples in general lighting, automotive technology, sensor technology
- Infrared LEDs, visible light, UV LEDs

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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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
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	PHY-AP-43	**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 cristals, plasmonics)
2. Production and characterisation (metrology) of nano structures
3. Photonic nano materials / meta materials / meta surfaces
4. Optic nano emitters and nano antennae
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.
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.
Participants are able to identify the basic elements in complex optical systems and describe their respective functions.
The participants can name important processes of micro- and nanostructuring and explain how they work.
The participants can solve the wave equation in simple dielectric, metallic and hybrid nanooptical systems analytically and semi-analytically and interpret the solutions.
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
Prasad: Nanophotonics, John Wiley & Sons 2004
Jahns, Helfert: Introduction to Micro- and Nanooptics, Wiley VCH 2012

↑

Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
Fundamentals of Nano Optics	2,0	Lecture	english
Fundamentals of Nano Optics	1,0	Exercise	english

Title	Nanoelectronics		
Number	2411200	Module version	
Shorttext	ET-EMG-20	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

- Quantum mechanics Wave function, potentials, interaction
- Magnetism
- Superconductivity
- Manufacturing processes
- Josephson junctions
- SET components
- Data memory
- THz transistors
- Quantum computing

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 availabe for the lecture
- R. Waser, #Nanoelectronics and Information Technology#, Wiley-VCH, 2003, ISBN 978-3527403639
- M. Köhler, #Nanotechnologie#, Wiley-VCH, 2007, ISBN 978-3527318711
- Jasprit Singh, #Modern Physics for Engineers#, Wiley, 1999, ISBN 978-0471330448
- N. Ashcroft, N. Mermin, #Solid State Physics#, Cengage Learning Services, 1976, ISBN 978-0030839931
- S. Flügge, #Rechenmethoden der Quantentheorie#, Springer Verlag 1993, ISBN 978-3540567769
- W. Nolting, #Quantenmechanik#, Band 5 aus #Grundkurs: Theoretische Physik#, Springer-Verlag, 2007, ISBN 978-3540688686

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
Nanoelectronics	2,0	Lecture	german

Literature

- R. Waser, Nanoelectronics and Information Technology, Wiley-VCH
- M. Köhler, Nanotechnologie, Wiley-VCH
- Jasprit Singh, Modern Physics for Engineers, Wiley
- N. Ashcroft, N. Mermin, Solid State Physics
- S. Flügge, Rechenmethoden der Quantentheorie
- W. Nolting, Quantenmechanik, Band 5 aus Grundkurs: Theoretische Physik

Nanoelectronics	1,0	Exercise	german

Literature

- R. Waser, Nanoelectronics and Information Technology, Wiley-VCH
- M. Köhler, Nanotechnologie, Wiley-VCH
- Jasprit Singh, Modern Physics for Engineers, Wiley
- N. Ashcroft, N. Mermin, Solid State Physics
- S. Flügge, Rechenmethoden der Quantentheorie
- W. Nolting, Quantenmechanik, Band 5 aus Grundkurs: Theoretische Physik

Title	Integrated Circuits		
Number	2413280	**Module version**	
Shorttext	ET-IHT-28	**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. Vadim Issakov
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Expected performance/ Type of examination	oral exam (20 min)		
Course achievement			

Contents

The module provides an overview of the operation, design, and technology of integrated electronic circuits in microelectronics.

- Introduction
- Basic digital circuits
- MOS and CMOS
- Silicon wafer manufacturing
- MOSFET process technology
- Nanolithography
- Etching techniques and oxidation
- Design automation, design rules, and assembly techniques
- Back-end technologies
- Modern developments: Memory technologies

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

Lecture slides and short script
J.M.Rabaey, A.Chandrakasan, B. Nikolic, Digital Integrated Circuits
Prentice Hall Electronics and VLSI Series, 2002 ISBN: 8120322576
A. Schlachetzki, Integrierte Schaltungen, Teubner, 1978, (as copy at IHT) ISBN: 3-519-03070-5
D. Widmann, H. Mader, H. Friedrich, Technologie Hochintegrierte Schaltungen, Springer,1996 ISBN:3540593578
W. Prost, Technologie der III/V Halbleiter, Springer, 1997 ISBN: 3540628045

↑

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

	2,0	Lecture	german
Literature			
Vorlesungsfolien und Kurzskript K.-H. Cordes, A. Waag, N. Heuck : Integrierte Schaltungen; Pearson Studium, 2010 J.M.Rabaey, A.Chandrakasan, B. Nikolic, Digital Integrated Circuits Prentice Hall Electronics and VLSI Series, 2003, 1996 A. Schlachetzki, Integrierte Schaltungen, Teubner, 1978, (als Kopie im IHT) D. Widmann, H. Mader, H. Friedrich, Technologie Hochintegrierte Schaltungen, Springer,1996 W. Prost, Technologie der III/V # Halbleiter, Springer, 1997			

	1,0	Exercise	german
Literature			
K.-H. Cordes, A. Waag, N. Heuck : Integrierte Schaltungen; Pearson Studium, 2010			

Title	Solar Cells		
Number	2413310	**Module version**	
Shorttext	ET-IHT-31	**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 *Klausur*+		
Course achievement			

Contents

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.

- Politics of renewable energies
- Physical basics of photovoltaic generation of electricity (sun radiation, absorption of radiation by semiconductors, p-n-junction, I-U-characteristics)
- Fabrication and structure of monocrystalline and multi-crystalline Solar cells
- Thin film solar cells, organic cells, dye cells
- Comparison of the different solar cell concepts
- Dimensioning of solar plants
- Applications

Objective qualification

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.

Literature

- Lecture slides and short script
- H.-G. Wagemann, A. Schmidt: Grundl. d. optoelektron. Halbleiterbauelemente; Teubner Stuttgart 1998 ISBN: 3-519-03240-6
- H.-G. Wagemann, H. Eschrich: Grundl. d. photovoltaischen Energieumwandlung; Teubner Stuttgart 1994 ISBN: 3-519-03218-X

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

	2,0	Lecture	german
Literature			
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	ET-IHT-33	**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

- Crystal-structure analysis, X-ray diffraction
- Lattice defects
- Epitaxial layers, nanostructures, lattice mismatch
- Microscopy (light, electrons, scanning probes), imaging modes, analytical electron microscopy
- Band structure, band gap, excitation spectroscopy, spatially resolved luminescence, effective mass
- Electrical transport properties, piezoresistive effect
- Charge carrier concentration and mobility, Hall method, CV method
- Optical absorption, Fourier transform spectroscopy
- Impurities and defects, chemical analysis, deep traps
- Minority carrier lifetime, diffusion length
- Metal-semiconductor junction, Schottky contact, Ohmic contact, sheet resistance
- Oxide layers, ellipsometry
- Device characteristics

Objective qualification

After completing the module semiconductor characterization, the students will have

- a basic understanding of the most important methods for characterizing semiconductor materials
- the ability to select appropriate quality control procedures in the manufacture of semiconductor devices
- 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

Literature

K. Kopitzki: Einführung in die Festköperphysik (Teubner, Stuttgart, 1989) ISBN: 3-519-13083-1
H. Alexander: Physikalische Grundlagen der Elektronenmikroskopie (Teubner, Stuttgart, 1997) ISBN: 3-519-03221-X
W. Prost: Technologie der III/V-Halbleiter: III/V-Heterostrukturen und elektronische Höchstfrequenz-Bauelemente
(Springer, Berlin, 1997) ISBN:3-540-62804-5
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.

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

Title	Thin Film Technology		
Number	2413350	**Module version**	
Shorttext	ET-IHT-35	**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. Andrey Bakin
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

Definitions, layer systems, alloys and compounds.
Growth model: adsorption, lifetime of adsorbed species, sticking coefficient, surface diffusion, chemosorption, nucleation, coalescence, real surfaces, surface passivation, surface energy, growth modes.
Epitaxy and deposition: layer morphology, texturing, vacuum requirements, convection, diffusion, molecular flow, collision cross-section, free path.
Vapor deposition: thermodynamics, vapor deposition of alloys and compounds. Molecular beam epitaxy, Knudsen cell. Cathode atomization (sputtering), ionization mechanisms, HF sputtering, magnetron sputtering, reactive sputtering, ion beam sputtering.
Chemical vapor deposition (CVD): reactions, thermodynamics and kinetics of CVD, different types of CVD: LPCVD, PECVD, MOCVD, ALD. Electroplating. Langmuir Blodget Layers. Monitoring and control of the layer deposition. Heterostructures, superlattices, nanostructures. Applications of thin-film technologies in nano-, opto-, magnetoelectronics, spintronics and outlook.

Objective qualification

After completing the thin-film technology module, students have
- a basic understanding of the most important methods for modeling, manufacturing and characterizing thin films (semiconductors, insulators, metal layers)
- the ability to recognize the principles of the most modern thin-film technologies and to understand how they work
- the ability to select suitable manufacturing processes for the realization of nano-, opto-, magneto- and micro-electronic structures
- in-depth knowledge in the development and optimization of thin-film technologies for new materials and nanoheterostructures
- the ability of assessing possible implementations of different thin-film technology processes
- the ability to analyze and extrapolate trends in thin-film technology developments as well as nanoelectronic, optoelectronic and magnetoelectronic heterostructure production

Literature

- Slides
- Thin Film Materials Technology, K. Wasa, M. Kitabatake, H. Adachi, Springer 2004, ISBN 0 8155 1483-2

- Materials Science of Thin Films, M. Ohring, Academic Press 2002, ISBN 0-12-524975-6

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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	Packaging and Interconnection Technology		
Number	2413390	Module version	
Shorttext	ET-IHT-39	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

- Open wiring, bread board, printed circuit board
- Thick film technologies, substrates, screen printing and pastes, thin film technology, photolithography
- Surface mount technology, components, housing forms, modern developments (TAB, BGA, flip chip, CSP, MCM)
- Power modules, special requirements
- Cooling, basics and problems, air cooling, liquid cooling
- Thermomechanical stresses and reliability, basics, examples
- Soldering
- Adhesive bonding
- Wire bonding
- Direct copper bonding
- Low-temperature joining technology

Objective qualification

After completing the module electronic packaging, the students will have
- a basic understanding of the most important processes for assembling and joining electronic devices and components
- the ability to select suitable processes for packaging in the manufacture of semiconductor modules
- in-depth knowledge and practical experience in the use, analysis and evaluation of methods of electronic packaging

Literature

W. Scheel (Hrsg.): Baugruppentechnologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) ISBN: 3-341-01100-5
H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01097-1
H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Hybridträger (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01099-8
M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiesbaden, 1991) ISBN: 3-528-06392-0

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

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

	1,0	Exercise	german
Literature			
Unterlagen werden verteilt.			

	2,0	Lecture	german
Literature			
W. Scheel (Hrsg.): Baugruppentechnologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994) H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Hybridträger (Verlag Technik, Berlin, Saulgau, 1994) M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiebaden, 1991)			

Title	Special Problems in Semiconductor Nano Technology		
Number	2413400	**Module version**	
Shorttext	ET-IHT-40	**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 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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	2,0	Advanced seminar	german
Literature			
individuell			

Title	Semiconductor Technology		
Number	2413420	**Module version**	
Shorttext	ET-IHT-42	**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/ Type of examination	Oral exam 30 min		
Course achievement			

Contents

- physical and chemical basics
- manufacturing of single crystals and wafers
- epitaxial crystal growth processes and crystal defects
- doping processes
- semiconductor measurement technology
- planar technology
- basics of photolithography, deposition processes for dielectrics and etching processes

Objective qualification

After completing the semiconductor technology module, students have:

- an understanding of the basic manufacturing technologies of semiconductors as well as components and integrated circuits made from them.
- the ability to recognize the principles of the most modern manufacturing processes in semiconductor technology and their modes of operation
- the ability to analyze and extrapolate trends in semiconductor technology developments

Literature

- Lecture transparencies
- Script in Englisch (H.-H. Wehmann and A. Schlachetzki)
- Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(Stuttgart, 1998) ISBN: 3-519-06167-8
- Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (Berlin, 1991) ISBN: 3-540-53873-9
- Werner Prost: Technologie der III/V-Halbleiter, Springer (Berlin, 1997) ISBN. 3-540-62804-5
- Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (Stuttgart, 2004) ISBN: 3-519-30149-0

Remark

Language German or English

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

Title	Nano- and Polycrystalline Materials		
Number	2413440	Module version	
Shorttext	ET-IHT-44	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. Andrey Bakin
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

- Overview, definitions, basics, the quantum nature of the nanoworld
- Surfaces of nano- and polycrystalline materials, phase changes of nanoparticles, thermodynamics of nanoparticles, heat capacity
- Manufacturing of nanoparticles
- Manufacturing of nanopillars, nanowires and nanotubes
- Manufacturing of 2D nanostructures and SLS
- Porosity and porosity measurements, adsorption isotherms, BET methods, mercury pressure methods
- Manufacturing of polycrystalline layers
- Models of thin polycrystalline layers. Influence of grain boundaries on charge carrier transport, band bending, characteristics, specific resistance and charge carrier mobility
- Characterization of nano- and polycrystalline materials
- Applications of nano- and polycrystalline materials

Objective qualification

After completing the module nano- and polycrystalline materials, students have
- a basic understanding of the most important methods for modeling, manufacturing and characterizing nano- and polycrystalline materials
- the ability to recognize the principles of the most modern nanotechnology and to understand how they work
- the ability to select suitable manufacturing processes for the implementation of nano-, poly-, magneto- and micro-electronic systems
- in-depth knowledge of the development and optimization of manufacturing processes for new materials and nanostructures
- the ability of assessing and evaluating possible implementations of different nano- and polycrystalline materials
- the ability to analyze and extrapolate trends in nano- and polycrystalline materials and nanoelectronic, optoelectronic, microelectronic and magnetoelectronic systems

Literature

- Slides

- Polycristalline Silicon for Integrated Circuits and Displays, T.Kamins, Kluwer Academic Press 1998 ISBN: 0-7923-8224-2

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
	2,0	Lecture	german
Literature			
Folien Polycristalline Silicon for Integrated Circuits and Displays, T.Kamins, Kluwer Academic Press 1998			
	1,0	Exercise	german

Title	Surfaces and Interfaces		
Number	2413450	**Module version**	
Shorttext	ET-IHT-45	**Language**	english
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. Andreas Waag
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement			
Contents			
Objective qualification			
Literature			
Skript, Folien Henzler, Göpel: Oberflächenphysik des Festkörpers, Teubner (2007) ISBN: 3519130475 Umbach: Oberflächenphysik			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	2,0	Lecture	german
Literature			
Skript, Folien Henzler, Göpel: Oberflächenphysik des Festkörpers Umbach: Oberflächenphysik			
	1,0	Exercise	german

Title	Nanotechniques in Microelectronics		
Number	2413460	**Module version**	
Shorttext	ET-IHT-46	**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. Andrey Bakin
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

- introduction, definitions, basics
- nanostructuring
- self-organized nanostructures
- printed electronics
- nanoimprint
- 2D materials
- 3D chip - new generation of integration
- new wiring and cooling concepts
- nanotechnology in joining technology and packaging
- new components with improved properties

Objective qualification

The students are able to assess the applications of nanotechnology in microelectronics and to evaluate the trends in nanotechnology development.

Literature

Slides
Nanostructured Materials and Nanotechnology, ed. Hari Singh Nalwa, Academic Press 2002, ISBN 0 12-513920-9
Nanotechnology for Microelectronics and Optoelectronics, J. Martinez-Duart, R. Martin-Palmer, F. Agullo-Rueda, Elsevier 2006, ISBN-13: 978-0-08-044553-3

↑

Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	2,0	Lecture	german
Literature			
# Folien # Nanostructured Materials and Nanotechnology, ed. Hari Singh Nalwa, Academic Press 2002, ISBN 0 12-513920-9 # Nanotechnology for Microelectronics and Optoelectronics, J. Martinez-Duart , R. Martin-Palmer, F. Agullo-Rueda, Elsevier 2006, ISBN-13: 978-0-08-044553-3			
	2,0	Exercise	german

Title	Nano- and Bioelectronic System		
Number	2413560	**Module version**	
Shorttext	ET-IHT-56	**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
growth, nanostructuring and characterization processes and tools (lithography, microscopy, raster probe technique, spectroscopy, nanotubes, nanowires, nanoparticles, hybrid nanostructures
bio-organic functionalization of surfaces (Langmuir-Blodgett, self-assembled monolayers on metals and semiconductors)
semiconductor nano- and biosensors based on different inorganic and organic nanomaterials
hybrid nanostructures for optoelectronics

Objective qualification

After completion of the module Nano- and Bioelectronic Systems, the students possess
- 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)
- 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
"Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer, 2nd. Ed. (2006): ISBN-13: 978-3540298557

Remark

primarily master module

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

	2,0	Lecture	german
Literature			
"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
Literature			
"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	Advanced Quantum Technologies for Engineers		
Number	2413570	**Module version**	
Shorttext	ET-IHT-57	**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

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 eduction. 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 #Persepctives of quantum technologies# [gemeinsame Stellungnahme von Leopoldina, acatech und Union der deutschen Akademien der Wissenschaften, ISBN 978-3-80473343-5, online available]

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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Related courses
Rules for the choice of courses
Compulsory attendance

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

Title	Laser metrology and material processing		
Number	2413580	**Module version**	
Shorttext	ET-IHT-58	**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/ Type of examination	oral exam (30 minutes) or written exam (120 minutes), depending on number of participants		
Course achievement	Presentation		
Contents			
Basic laser technology generation of ultrashort laser pulses characterization of laser beams and laser pulses spectroscopy with sub-nanosecond time resolution basics of nonlinear optics light-matter interaction laser-based material processing of semiconductors modern spectroscopy methods in semidonductor 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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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	Molecular Electronics		
Number	2413600	**Module version**	
Shorttext	ET-IHT-60	**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
basic considerations (molecular orbitals, conjugated systems)
characterisation tools
transport mechanisms
conductive polymers
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
Polymer Electronics, M. Geoghegan, G. Hadziioannou, Oxford

↑

Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
Molecular Electronics	2,0	Lecture	english
Literature			
"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
Literature			
lecture slides, exercise materials			

Title	Optical Communications with Lab		
Number	2415220	Module version	
Shorttext	ET-IHF-22	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/ Type of examination	Written exam (120 minutes) or oral exam (30 minutes)		
Course achievement			

Contents

- Optical fibers
- Dispersion, velocities of light
- Coherent modulation
- Coherent receiver
- Laser
- Optical amplifier
- Optoelectronic modulators
- Photodetectors
- Systems of optical communications

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

↑

Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language

	2,0	Lecture	german
Literature			
- Skript zur Vorlesung - S. L. Chuang, Physics of Optoelectronic Devices, John Wiley & Sons			

	1,0	Exercise	german

	1,0	Laboratory	english
Literature			
Skript zum Praktikum			

Title	Dielectric Materials for Electronics and Photonics		
Number	2415250	**Module version**	
Shorttext	ET-IHF-25	**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

- Crystalline solids
- Reciprocal lattice
- X-ray deflection
- Phonons
- Dielectric properties of insulators (local electric field, mechanisms of polarization, Krames-Kronig relations)
- Thermal properties of insulators (Specific heat, thermal expansion, thermal conductivity)
- Magnetic properties of diamagnetism and paramagnetism
- Ferro-, antiferro-, and ferrimagnetism

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

- Skript zur Vorlesung - N. W. Ashcroft, N. D. Mermin, Solid State Physics, Thompson Press, ISBN 8131500527
- C. Kittel, Einführung in die Festkörperphysik, Oldenbourg, ISBN 3486577239

↑

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

	2,0	Lecture	german
Literature			
- 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	ET-IHF-29	**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/ Type of examination	Written exam (90 min) or oral exam (30 min) or presentation		
Course achievement			

Contents

- Propagation of electromagnetic waves in free space and in guiding structures
- Refraction, reflexion, total reflexion at dielectric interfaces
- Optical guiding in film and strip waveguides, mechanisms of losses
- Optical modes and theoretical description
- field distribution in step and gradient profiles, analogy to quantum mechanics
- Periodic structures to distributed feedback: DFB, DBR
- Electrooptical interaction, directional couplers

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

↑

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	Quantum Structure Devices		
Number	2415310	**Module version**	
Shorttext	ET-IHF-31	**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)	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

- Schroedinger wave equation
- Potential wells
- Semicondustor materials for quantum structure devices
- Electronical quantum well devices
- Emission and absorption (Einstein relations, Fermi´s golden rule, electron photon interaction)
- Excitons
- Photonic quantum well devices
- Quantum wire and quantum box, one and zero dimensional electronic structures
- Semiconductor devices based on one and zero dimensional quantum strutures
- Tunneling, tunnel diode, resonant tunnel diode

Objective qualification

After completion of the module students have deeper understanding of quantummechanical phenomena in semiconductor devices. They have the ability to design and dimension quantum structures.

Literature

Schiff, Quantum Mechanics, McGraw Hill, ISBN 0070552878

↑

Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**

Quantum Structure Devices	2,0	Lecture	english
Literature			
- Skript zur Vorlesung - L. I. Schiff, Quantum Mechanics, McGraw Hill			

Quantum Structure Devices	1,0	Exercise	english

Title	Organic Optoelectronics		
Number	2415430	**Module version**	
Shorttext	ET-IHF-43	**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/ Type of examination	written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

- Applications of organic materials in electronics and optics
- Molecular structure and chem. bonds
- Charge injection, charge transport in organic semiconductors
- Electrooptical Processes
- Process technology for organic materials
- Applications: Organic light emitting diodes, lasers, solar cells, transistors, sensors

Objective qualification

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.
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.

Literature

Schwoerer, Wolf, Organische Molekulare Festkörper, Wiley-VCH, ISBN 3527405399

↑

Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**

	1,0	Exercise	german
	2,0	Lecture	german

Title	Organic Optoelectronics		
Number	2415440	Module version	
Shorttext	ET-IHF-44	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

- Applications of organic materials in electronics and optics
- Molecular structure and chem. bonds
- Charge injection, charge transport in organic semiconductors
- Electrooptical Processes
- Process technology for organic materials
- Applications: Organic light emitting diodes, lasers, solar cells, transistors, sensors

Objective qualification

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.
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.

Literature

Schwoerer, Wolf, Organische Molekulare Festkörper, Wiley-VCH, ISBN 3527405399

↑

Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language

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

Title	Nonlinear Photonics		
Number	2415470	**Module version**	
Shorttext	ET-IHF-47	**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

- Basics of linear optics
- 2nd order nonlinear optical effects
- 3rd order nonlinear optical effects
- Nonlinear scattering
- Optical telecommunications
- Nonlinear effects in optical fibers
- Suppression of nonlinear effects
- Applications of nonlinear effects

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

↑

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

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

Title	Linear photonics with practical course		
Number	2415500	Module version	
Shorttext	ET-IHF-50	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)

↑

Related courses

Rules for the choice of courses

Compulsory attendance

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

	2,0	Internship	german
Literature			
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	ET-IHF-51	**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

↑

Related courses

Rules for the choice of courses

Compulsory attendance

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	ET-IEMV-07	**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
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
- quantitative description of radiation properties by special numerical calculation methods - theoretical concepts of mainstream methods (FE, FD, MoM) and newer approaches (i.a. wavelets) - criteria of bandwidth and complexity of boundary conditions - practical sample applications from EMC (absorption in technical materials and biological tissue, shielding and antenna development)
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 # Matthew N.O. Sadiku, Numerical Techniques in Electromagnetics, CRC Press, Boca Raton, 2001, ISBN 0-8493-1395-3

↑

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	Electromagnetic Compatibility		
Number	2419120	**Module version**	
Shorttext	ET-IEMV-12	**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
Hours per Week / ECTS	3 / 5,0	**Module owner**	Dr. Harald Spieker
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

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices #
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference #
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection #
- Legal basis, product liability, standardization #
- EMC test engineering #
- Electromagnetic compatibility of biological systems

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

- Lecture notes
- Joachim Franz, EMV – Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

↑

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

Title	Electromagnetic Compatibility with Seminar		
Number	2419130	**Module version**	
Shorttext	ET-IEMV-13	**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
Hours per Week / ECTS	5 / 6,0	**Module owner**	
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

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection
- Legal basis, product liability, standardization
- EMC test engineering
- Electromagnetic compatibility of biological systems
- Current EMC issues presented in seminar talks

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

- continuously updated script handout
- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

↑

Related courses

Rules for the choice of courses

You can either choose Electromagnetic Compatibility with Seminar **or** Electromagnetic Compatibility (without seminar). The seminar can also be attened in the summer semester after having attended the EMC lecture.

Compulsory attendance

Name of the course	SWS	Eventtype	Language
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	ET-BST-14	**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

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.

The lecture is divided into the following chapters:

- High-frequency amplifier circuits
- Simulation of electronic noise
- Low-noise input amplifiers in CMOS
- Mixer circuits
- HPhase-locked loops (PLLs)
- Voltage-controlled oscillators

Objective qualification

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).

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.
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

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	ET-BST-15	**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

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.

The lecture is divided into the following chapters:
- High frequency amplifier circuits
- Simulation of electronic noise
- Low-noise input amplifiers in CMOS
- Mixer circuits
- Phase-locked loops (PLLs)
- Voltage-controlled oscillators

Objective qualification

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).

Literature

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

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Related courses			
Rules for the choice of courses			
Prerequisite for this module: Circuit Design (ST)			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
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	ET-BST-19	**Language**	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/ Type of examination	Oral exam (30 min) or written exam (90 min)		
Course achievement			

Contents

- Introduction to biomedical applications
- Biosensing principles (physical, electrical and electrochemical)
- Basic biomedical circuits: transimpedance and instrumentation amplifiers, oscillators, ADCs/DACs
- Basic circuits for Power Management (DCDC, LDO, Rectifier)
- Self-powering and energy storage (e.g. biofuel cell sensing, energy harvesting)
- Wireless Power Transfer (WPT) for implantable devices
- Circuits for ultra-low power data transmission
- Circuits for electrochemical sensing (potentiometric and amperometric)
- Examples of potentiometric biosensors (pH, K+, Na+, Ca+ etc) and iontophoresis
- Circuits for Impedance Spectroscopy
- Radar-based Imaging for Breast Cancer Detection
- Circuits for Electrical Impedance Tomography
- Resonance-based dielectric sensors (e.g. for glucose detection)
- Circuits for cochlear implants

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
“Power Management Integrated Circuits (Devices, Circuits, and Systems)”, M. Hella, P. Mercier, CRC Press, 2016
“Introduction to Biosensors From Electric Circuits to Immunosensors”, J.-Y. Yoon, Springer 2016

↑

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

	2,0	Lecture	german
Literature			
?Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems?, Rahul Sarpeshkar, Cambridge University Press, 2010 ?Power Management Integrated Circuits (Devices, Circuits, and Systems)?, M. Hella, P. Mercier, CRC Press, 2016 ?Introduction to Biosensors From Electric Circuits to Immunosensors?, J.-Y. Yoon, Springer 2016			

	2,0	Exercise	german
Literature			
?Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems?, Rahul Sarpeshkar, Cambridge University Press, 2010 ?Power Management Integrated Circuits (Devices, Circuits, and Systems)?, M. Hella, P. Mercier, CRC Press, 2016 ?Introduction to Biosensors From Electric Circuits to Immunosensors?, J.-Y. Yoon, Springer 2016			

Title	Low power CMOS data converter circuit design		
Number	2420210	Module version	
Shorttext	ET-BST-21	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

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.

General introduction of data converters
1. Data converter application areas
Sensor interface, Communication (wireless/wireline)
2. Basic theory in data conversion
Sampling/Quantization, Performance metric (INL/DNL, SNDR, SFDR, ENOB, FoM)
3. Architectures and features of data converters
2-1. High resolution data converter (SAR, ##, VCO based)
2-2. High speed data converter (Flash, Pipeline)

Implementation of low-power and high-resolution CMOS integrated ADCs
4. Building blocks of ADC
Comparator, operational amplifier
5. SAR-ADC with charge redistribution.
3-1. Power reduction techniques
3-2. Resolution enhancement techniques (digital calibration etc.)
6. High resolution ## modulator
7. Time based (VCO based) ADC
8. Hybrid-ADC
9. Characterization of data converters

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	ET-IHT-62	**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

- Basics of Quantum Mechanics
- From Bit to Qubit
- Quantum Circuits I
- Quantum Circuits II
- Entanglement and Teleportation
- Algorithms of Quantum Computing
- Quantum Hardware I
- Quantum Hardware II

Objective qualification

- The students can name the prerequisites for the realization of qubits as well as typical platforms and explain their significance.
- Students will be able to name the strengths and weaknesses of different hardware platforms in common application scenarios and weigh them against each other.
- 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.
- Students will be able to use an exemplary platform to explain how selected quantum gates can be realized.

Literature

[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019
[2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010
[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019
[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018
[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019

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

Applied Quantum Computing: Basics and Devices	2,0	Lecture	german
Literature			
[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019 [2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010 [3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019 [4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018 [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	ET-IHT-32	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/ Type of examination	oral exam (30 min) or written exam (90 min)		
Course achievement			

Contents

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

- Introduction and overview
- The nature of light: physical principles
- The human perception of light
- Production and design of light sources
- Module structure
- Energy balances
- Standardisation
- Applications (lighting technology,
- Automotive Lighting)

[Lighting technology (V)]
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.

[Lighting technology (Ü)]
- Introduction and overview
- The nature of light: physical principles
- The human perception of light
- Production and construction of light sources
- Module structure
- Energy balances
- Standardisation

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

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

	2,0	Lecture	german
Literature			
Vorlesungsfolien und Kurzskript 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/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

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:

- Physical principles of LEDs. Band gap engineering in LEDs.
- Semiconductor materials for optoelectronics
- Relationship between material properties and LED properties
- Manufacturing processes
- Efficiency considerations
- Front-end and back-end processing
- Application examples in general lighting, automotive technology, sensor technology
- Infrared LEDs, visible light, UV LEDs

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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
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/ 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

- Fox: Optical Properties of Solids,
- Davies: The Physics of low-dimensional semiconductors,
- Yu and Cardona: Fundamentals of Semiconductors,
- Kalt and Klingshirn: Semiconductor Optics 1,
- Grundmann: The Physics of Semiconductors,
- Marx und Gross: Festkörperphysik,
- Hungklinger: Festkörperphysik

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
Semiconductor Optics	2,0	Lecture	english
Literature			
• Fox: Optical Properties of Solids, • Davies: The Physics of low-dimensional semiconductors, • Yu and Cardona: Fundamentals of Semiconductors, • Kalt and Klingshirn: Semiconductor Optics 1, • Grundmann: The Physics of Semiconductors, • Marx und Gross: Festkörperphysik, • Hungklinger: Festkörperphysik			
Semiconductor Optics	1,0	Exercise	english
Literature			
• Fox: Optical Properties of Solids, • Davies: The Physics of low-dimensional semiconductors, • Yu and Cardona: Fundamentals of Semiconductors, • Kalt and Klingshirn: Semiconductor Optics 1, • Grundmann: The Physics of Semiconductors, • Marx und Gross: Festkörperphysik, • Hungklinger: Festkörperphysik			

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

- System overview
- Jitter and phase noise
- Basic PLL architectures
- Analog integer PLL
- Digital integer PLL
- Fractional PLL
- Clock data recovery
- Delay locked loop
- Numerically controlled oscillator
- Software PLL

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
Behzad Razavi “Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level”, Cambridge University Press, 2020

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

Phase-Locked Loops and Frequency Synthesis	2,0	Lecture	english
Literature			
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
Literature			
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/ 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
2. Oberflächenphysik des Festkörpers, M. Henzler und W. Göpel, Teubner Studienbücher, 1994
3. Oberflächenphysik, Grundlagen und Methoden, T. Fauster, L. Hammer, K. Heinz, und M.A. Schneider, Oldenbourg Verlag München, 2013
4. Scanning Probe Microscopy and Spectroscopy, R. Wiesendanger, Cambridge University Press, 1994
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
Literature			
1. Physics at Surfaces, A. Zangwill, Cambridge University Press, 1988 2. Oberflächenphysik des Festkörpers, M. Henzler und W. Göpel, Teubner Studienbücher, 1994 3. Oberflächenphysik, Grundlagen und Methoden, T. Fauster, L. Hammer, K. Heinz, und M.A. Schneider, Oldenbourg Verlag München, 2013 4. Aktuelle Publikationen			

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/ 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

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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:

- Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010
- Horowitz & Hill: The Art of Electronics (2nd ed), CUP, 1989

Supplementary:

- Pallás-Areny & Webster: Analog Signal Processing, Wiley, 1999
- MIT OCW readings & lecture notes from MAS#836 Sensor Technologies
- Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
Sensor Technology	2,0	Lecture	english

Literature

Core Texts:

- Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010
- Horowitz & Hill: The Art of Electronics (2nd ed), CUP, 1989

Supplementary:

- Pallás-Areny & Webster: Analog Signal Processing, Wiley, 1999
- MIT OCW readings & lecture notes from MAS#836 Sensor Technologies
- Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)

Sensor Technology	1,0	Exercise	english

Literature

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	PHY-AP-43	**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 cristals, plasmonics)
2. Production and characterisation (metrology) of nano structures
3. Photonic nano materials / meta materials / meta surfaces
4. Optic nano emitters and nano antennae
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.
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.
Participants are able to identify the basic elements in complex optical systems and describe their respective functions.
The participants can name important processes of micro- and nanostructuring and explain how they work.
The participants can solve the wave equation in simple dielectric, metallic and hybrid nanooptical systems analytically and semi-analytically and interpret the solutions.
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
Prasad: Nanophotonics, John Wiley & Sons 2004
Jahns, Helfert: Introduction to Micro- and Nanooptics, Wiley VCH 2012

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
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	ET-EMG-16	**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

- Characteristics of measuring sensors
- Temperature measurement
- Magnetic field measurement
- Optical sensors
- Measurement of geometric quantities
- Measurement of dynamometric quantities
- Flow measurement

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

- P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag), ISBN 978-3486225921
- H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart), ISBN 978-3519061250
- J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag), ISBN 978-3540622314 ?#8226? J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig), ISBN 978-3446219779

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
	2,0	Lecture	german

Literature

P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)
H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)
J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)
J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)

	2,0	Exercise	german

Literature

P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)
H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)
J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)
J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)

	3,0	Laboratory	german

Literature

P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag)
H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart)
J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag)
J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)

Title	Digital Signal Processing with Microcontrollers with Experiments		
Number	2411170	**Module version**	
Shorttext	ET-EMG-17	**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,
Interpolation of measurement data,
Signal analysis: discrete (DFT) and fast (FFT) Fourier transformation
z-transform: digital filters, correlation, simulation of a closed control loop,
Controller and controlled system as IIR and FIR filters.
Assembly language of microprocessors
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
- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984, ISBN 978-3519001416
- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985, ISBN 978-3486298451
- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979, ISBN 978-3486245288
- 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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Lecture	german

Literature

- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984
- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985
- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979
- Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983

	1,0	Exercise	german

Literature

- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984
- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985
- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979
- Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983

Title	Laser metrology and material processing		
Number	2413580	**Module version**	
Shorttext	ET-IHT-58	**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/ Type of examination	oral exam (30 minutes) or written exam (120 minutes), depending on number of participants		
Course achievement	Presentation		

Contents

Basic laser technology
generation of ultrashort laser pulses
characterization of laser beams and laser pulses
spectroscopy with sub-nanosecond time resolution
basics of nonlinear optics
light-matter interaction
laser-based material processing of semiconductors
modern spectroscopy methods in semidonductor 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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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	Microwave and Wireless Metrology		
Number	2424530	**Module version**	
Shorttext	ET-NT-53	**Language**	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 (30 min)		
Course achievement			

Contents

- Introduction to metrology
- Fundamentals of high-frequency technology
- Measurements in the time domain
- Spectrum analysis
- Vector network analysis
- Antenna measurement technology
- Channel measurements
- Protocol measurement technology

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

- Slides
- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde & Schwarz, 2004
- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde & Schwarz, 2007
- A.Molisch: Wireless Communications, Wiley, 2005

Remark

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

	2,0	Lecture	german
Literature			
- Foliensammlung - C.Rauscher: Grundlagen der Spektrumanalyse, Rohde & Schwarz, 2004 - M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde & Schwarz, 2007 - A.Molisch: Wireless Communications, Wiley, 2005			

	2,0	Exercise	german
Literature			
- Foliensammlung - C.Rauscher: Grundlagen der Spektrumanalyse, Rohde & Schwarz, 2004 - M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde & Schwarz, 2007 - A.Molisch: Wireless Communications, Wiley, 2005			

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/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

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:

- Physical principles of LEDs. Band gap engineering in LEDs.
- Semiconductor materials for optoelectronics
- Relationship between material properties and LED properties
- Manufacturing processes
- Efficiency considerations
- Front-end and back-end processing
- Application examples in general lighting, automotive technology, sensor technology
- Infrared LEDs, visible light, UV LEDs

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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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
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	PHY-AP-43	**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 cristals, plasmonics)
2. Production and characterisation (metrology) of nano structures
3. Photonic nano materials / meta materials / meta surfaces
4. Optic nano emitters and nano antennae
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.
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.
Participants are able to identify the basic elements in complex optical systems and describe their respective functions.
The participants can name important processes of micro- and nanostructuring and explain how they work.
The participants can solve the wave equation in simple dielectric, metallic and hybrid nanooptical systems analytically and semi-analytically and interpret the solutions.
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
Prasad: Nanophotonics, John Wiley & Sons 2004
Jahns, Helfert: Introduction to Micro- and Nanooptics, Wiley VCH 2012

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Fundamentals of Nano Optics	2,0	Lecture	english
Fundamentals of Nano Optics	1,0	Exercise	english

Title	Gravitational Wave Detection		
Number	1520440	**Module version**	
Shorttext	PHY-AP-44	**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

- Gravitational waves and their sources
- Historical development of gravitational wave detectors
- Interferometric gravitational wave detectors
- Noise processes in opto-mechanical systems
- Future gravitational wave detectors

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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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Gravitational Wave Detection	2,0	Lecture	german
Gravitational Wave Detection	1,0	Exercise	german

Title	Sensors with Lab		
Number	2411160	**Module version**	
Shorttext	ET-EMG-16	**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

- Characteristics of measuring sensors
- Temperature measurement
- Magnetic field measurement
- Optical sensors
- Measurement of geometric quantities
- Measurement of dynamometric quantities
- Flow measurement

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

- P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag), ISBN 978-3486225921
- H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart), ISBN 978-3519061250
- J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag), ISBN 978-3540622314 ?#8226? J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig), ISBN 978-3446219779

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

	2,0	Lecture	german
Literature			
P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag) H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart) J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag) J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)			

	2,0	Exercise	german
Literature			
P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag) H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart) J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag) J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)			

	3,0	Laboratory	german
Literature			
P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag) H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart) J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag) J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)			

Title	Digital Signal Processing with Microcontrollers with Experiments		
Number	2411170	**Module version**	
Shorttext	ET-EMG-17	**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,
Interpolation of measurement data,
Signal analysis: discrete (DFT) and fast (FFT) Fourier transformation
z-transform: digital filters, correlation, simulation of a closed control loop,
Controller and controlled system as IIR and FIR filters.
Assembly language of microprocessors
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
- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984, ISBN 978-3519001416
- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985, ISBN 978-3486298451
- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979, ISBN 978-3486245288
- 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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Lecture	german

Literature

- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984
- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985
- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979
- Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983

	1,0	Exercise	german

Literature

- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984
- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985
- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979
- Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983

Title	Bioanalysis		
Number	2411180	**Module version**	
Shorttext	ET-EMG-18	**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

- Cell: Structure and cell division
- Cell nucleus and chromosomes
- Genetic code
- From DNA to protein
- Electrochemical basics
- Separation methods
- Cell disruption and PCR
- NMR spectroscopy
- Optical spectroscopy
- Microscopy
- Marker-based analysis methods
- Functional analysis
- Biochips / Lab on a Chip
- Immune system

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
- M. Madigan et al., Brock - Mikrobiologie, Spektrum Akad. Verlag, ISBN 978-3827405661
- G.M. Cooper, R. E. Hausman, The Cell, ASM Press / Sinauer Assoc. Sunderland MA, ISBN 978-0878932207
- Hans Naumer und Wolfgang Heller (Hrsg.), Untersuchungsmethoden in der Chemie, Georg Thieme Verlag, Stuttgart, 1990, ISBN 978-3136814031

- F. Lottspeich/H. Zorbas, Bioanalytik, Spektrum Akademischer Verlag Heidelberg 1998, ISBN 978-3827400413
Remark
Mainly for Master's students.

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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	ET-EMG-19	**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 numbers of participants		
Course achievement			

Contents

- Introduction to biomedical technology
- Physiological systems and biomedical parameters
- Development of cell potentials
- Measurement of potentials in the cell
- Electrocardiogram (ECG)
- Electroencephalography (EEG)
- Electromyography (EMG)
- Biomagnetic signals
- Cardiovascular diagnostics
- Pulmonary function diagnostics
- Pulse oximetry
- Ultrasound diagnostics
- X-ray diagnostics and computer tomography (CT)
- Magnetic resonance imaging (MRI)

Objective qualification

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.

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.

Literature

A multimedia-CD-ROM with script and exercises is offered for the lecture
- J. J. Carr , J.M. Brown, Introduction to Biomedical Equipment Technology, Prentice Hall, 4th ed., Upper Saddle River 2001, ISBN 978-8177588835
- J. L. Prince, J. M. Links , Medical Imaging: Signals and Systems, Pearson/Prentice Hall, 1st ed., Upper Saddle River 2006, ISBN 978-0130653536

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

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

	1,0	Exercise	german
Literature			
• J. J. Carr , J. M. Brown, #Introduction to Biomedical Equipment Technology#, Prentice Hall, 4th ed., Upper Saddle River 200# • J. L. Prince, J. M. Links, #Medical Imaging: Signals and Systems# Pearson/Prentice Hall, 1st ed., Upper Saddle River 2006 • J. Eichmeier, #Medizinische Elektronik#, Springer Verlag, 3. Auflage Berlin 1997			

	2,0	Lecture	german
Literature			
• J. J. Carr , J. M. Brown, #Introduction to Biomedical Equipment Technology#, Prentice Hall, 4th ed., Upper Saddle River 200# • J. L. Prince, J. M. Links, #Medical Imaging: Signals and Systems# Pearson/Prentice Hall, 1st ed., Upper Saddle River 2006 • J. Eichmeier, #Medizinische Elektronik#, Springer Verlag, 3. Auflage Berlin 1997			

Title	Nanoelectronics		
Number	2411200	**Module version**	
Shorttext	ET-EMG-20	**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

- Quantum mechanics Wave function, potentials, interaction
- Magnetism
- Superconductivity
- Manufacturing processes
- Josephson junctions
- SET components
- Data memory
- THz transistors
- Quantum computing

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 availabe for the lecture
- R. Waser, #Nanoelectronics and Information Technology#, Wiley-VCH, 2003, ISBN 978-3527403639
- M. Köhler, #Nanotechnologie#, Wiley-VCH, 2007, ISBN 978-3527318711
- Jasprit Singh, #Modern Physics for Engineers#, Wiley, 1999, ISBN 978-0471330448
- N. Ashcroft, N. Mermin, #Solid State Physics#, Cengage Learning Services, 1976, ISBN 978-0030839931
- S. Flügge, #Rechenmethoden der Quantentheorie#, Springer Verlag 1993, ISBN 978-3540567769
- W. Nolting, #Quantenmechanik#, Band 5 aus #Grundkurs: Theoretische Physik#, Springer-Verlag, 2007, ISBN 978-3540688686

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

Nanoelectronics	2,0	Lecture	german
Literature			
• R. Waser, Nanoelectronics and Information Technology, Wiley-VCH • M. Köhler, Nanotechnologie, Wiley-VCH • Jasprit Singh, Modern Physics for Engineers, Wiley • N. Ashcroft, N. Mermin, Solid State Physics • S. Flügge, Rechenmethoden der Quantentheorie • W. Nolting, Quantenmechanik, Band 5 aus Grundkurs: Theoretische Physik			

Nanoelectronics	1,0	Exercise	german
Literature			
• R. Waser, Nanoelectronics and Information Technology, Wiley-VCH • M. Köhler, Nanotechnologie, Wiley-VCH • Jasprit Singh, Modern Physics for Engineers, Wiley • N. Ashcroft, N. Mermin, Solid State Physics • S. Flügge, Rechenmethoden der Quantentheorie • W. Nolting, Quantenmechanik, Band 5 aus Grundkurs: Theoretische Physik			

Title	Precision Measuring Techniques		
Number	2411210	**Module version**	
Shorttext	ET-EMG-21	**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/ Type of examination	oral exam (30 min); written exam (120 min) only in case of large numbers of participants		
Course achievement			

Contents

- Measuring at physical limits
- Fundamentals of quantum effects and construction of precision devices
- Electrical and magnetic properties of Josephson elements,
- SQUIDs (Superconducting Quantum Interference Devices), SETs (Single Electron Tunnelling),
- Cryogenic current comparators and quantised resistors
- Accurate DC and AC voltage sources
- Measurement of small electrical voltages, currents, charges and magnetic fields
- Application examples in medicine, research and industry.

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
J. Hoffmann "Handbuch der Messtechnik", Hanser Verlag 2004, ISBN 3-446-21123-3
F. Kohlrausch "Praktische Physik" Teubner Verlag 1996, ISBN 3-519-23000-3
K. Kopitzki "Einführung in die Festkörperphysik" Teubner-Verlag 2007, ISBN 3-835-10144-7
W. Buckel und R. Kleiner "Supraleitung", Wiley-VCH Verlag, Weinheim, 2004, ISBN 3-527-40348-5
Further literature will be announced during the lecture

Remark

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

	2,0	Lecture	german
Literature			
Wird in der Vorlesung bekannt gegeben			

	1,0	Exercise	german

Title	Quality Assurance and Optimization		
Number	2411220	**Module version**	
Shorttext	ET-EMG-22	**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
Systematic and random measurement uncertainties/errors Noise and noise analysis
Determination of measurement uncertainty according to GUM
Fundamentals of applied statistics: distribution functions, estimation theory, hypothesis tests, error propagation
Equalisation calculation, regression analysis
Statistical design of experiments
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
- W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall 1991), ISBN 978-0023805523
- O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag 1978), ISBN 978-3411001194
- N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons 1977), ISBN 978-0471017561 und 978-0471017578
- Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig 1974, im Bibliotheksbestand
- 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

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

	2,0	Lecture	german

Literature

- #E. Schrüfer: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall)
- O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag)
- N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons)
- Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig
- B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH)
- G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)

	2,0	Exercise	german

Literature

- #E. Schrüfer: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall)
- O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag)
- N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons)
- Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig
- B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH)
- G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)

Title	Basics of Medicine for Engineers		
Number	2411280	**Module version**	
Shorttext	ET-EMG-28	**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/ Type of examination	Written exam (90 min)		
Course achievement			

Contents

- Introduction
- Cardiac anatomy, circulation
- Lungs, breathing, ventilation, endoscopy, bronchoscopy
- Heart-lung machine, circulatory support, artificial hearts
- Heart rhythm / cardiac arrhythmias
- Coronary anatomy, myocardial infarction (diagnosis and therapy), resuscitation
- Pacemakers, cardiac arrhythmias
- Surgical techniques
- Monitoring and intensive care
- Legal aspects of medical treatment
- Repetition

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.

- 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.
Registration starts in March on institute website.

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

	2,0	Lecture	german
Literature			
Zur Vorlesung wird eine Multimedia-CD-ROM mit Skript und Übungen angeboten, zusätzlich zum Download auf der Homepage des Instituts - Schäffler A, Mencke N: Mensch Körper Krankheit, #Anatomie, Physiologie, Krankheitsbilder Lehrbuch und Atlas für die Berufe im Gesundheitswesen#, Urban & Fischer, München Jena 1999, - Kramme R. #Medizintechnik: Verfahren, Systeme, Informationsverarbeitung# Springer, Berlin Heidelberg New York			

	1,0	Exercise	german
Literature			
Zur Vorlesung wird eine Multimedia-CD-ROM mit Skript und Übungen angeboten, zusätzlich zum Download auf der Homepage des Instituts - Schäffler A, Mencke N: Mensch Körper Krankheit, #Anatomie, Physiologie, Krankheitsbilder Lehrbuch und Atlas für die Berufe im Gesundheitswesen#, Urban & Fischer, München Jena 1999, - Kramme R. #Medizintechnik: Verfahren, Systeme, Informationsverarbeitung# Springer, Berlin Heidelberg New York			

Title	Measurement Electronics with Experiments		
Number	2411330	Module version	
Shorttext	ET-EMG-33	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/ 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

Measuring amplifiers with transistors and OPVs
- Electronic switches
- Source circuits
- Measuring transducers
- Analogue filter circuits
- Treatment of interference signals and noise
- Correlation analysis
- Measurement converters (A/D and D/A)
- Measuring device buses
- Time measurement
- Oscilloscopes and trigger circuits

and

carrying out experiments in the following areas
- Electronically controllable switches
- Reference sources for voltages and currents
- Measuring amplifiers
- Analogue-to-digital/digital-to-analogue converters
- Time and frequency measurement
- Oscilloscope
- Correlator

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 availabe 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

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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

Name of the course	SWS	Eventtype	Language
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

Name of the course	SWS	Eventtype	Language
Electronics measurement internship	3,0	Internship	german

Literature

Internship script

Title	Additive Manufacturing (3D-Printing)		
Number	2411340	**Module version**	
Shorttext	ET-EMG-28	**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/ Type of examination	oral exam (30 min) or written exam (120 min)		
Course achievement			

Contents

Printing Processes
Design with CAD
Slicer
G-Code
Print parameters
Printer electronics and sensors
Printing materials
Printing errors
Post-treatment
Applications

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.
presented by the group.

Objective qualification

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.

Literature

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

Title	Identification of Dynamic Systems		
Number	2412380	**Module version**	
Shorttext	ET-IFR-38	**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/ 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

- E. Hänsler: Statistische Signale
- Grundlagen und Anwendungen, Springer-Verlag, ISBN: 978-3540416449
- R. Isermann: Identifikation dynamischer Systeme I & II, Springer-Verlag, ISBN: 978-3540549246 & 978-3540554684
- L. Ljung: System Identification, Prentice Hall, ISBN: 978-0136566953
- W. Leonhard: Statistische Analyse linearer Regelsysteme, Teubner-Verlag, ISBN: 978-3519020462

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language

	2,0	Lecture	german
	2,0	Exercise	german

Title	Data Bus Systems		
Number	2412400	**Module version**	
Shorttext	ET-IFR-40	**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), depending on the number of participants		
Course achievement			
Contents			
- Bus architectures and access methods - Physical layers - Network and transport layer according to ISO layer model using the example of the OSEK standard for Network communication and management - LIN, CAN, TTP, FlexRay, MOST and Bluetooth - Interbus, Profibus, HART, ASI - Procedure for the selection of a suitable data bus system for a selected application			
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			
- Zimmermann, Schmidgall, Bussysteme in der Fahrzeugtechnik, Vieweg Verlag 2006, ISBN 3-8348-0166-6 - G. Schnell, B. Wiedemann, Bussysteme in der Automatisierungs- und Prozesstechnik, Vieweg Verlag 2006, ISBN 3-8348-0045-7			

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Related courses			
Rules for the choice of courses			
both lectures and exercises must be attended			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Lecture	german
Literature			
- Folienssammlung - Literaturempfehlungen in der Vorlesung - Etschberger, Controller-Area-Network, Hanser Verlag - Grzemba: LIN-Bus, Franzis Verlag - Rausch: Flexray, Hanser Verlag - Schäuffele: Automotive Software Engineering, Vieweg Verlag - Zimmermann: Bussysteme in der Fahrzeugtechnik, Vieweg Verlag - Schnell, Wiedemann: Bussysteme in der Automatisierungs- und Prozesstechnik			

	1,0	Exercise	german

Title	Nonlinear Control Systems		
Number	2412670	**Module version**	
Shorttext	ET-IFR-46	**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.
With the help of Lyapunov's stability theory, students are able to describe the rest positions of non-linear systems and assess their stability.
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.
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.
limit cycles.
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
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"

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

Title	Semiconductor Metrology		
Number	2413330	**Module version**	
Shorttext	ET-IHT-33	**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

- Crystal-structure analysis, X-ray diffraction
- Lattice defects
- Epitaxial layers, nanostructures, lattice mismatch
- Microscopy (light, electrons, scanning probes), imaging modes, analytical electron microscopy
- Band structure, band gap, excitation spectroscopy, spatially resolved luminescence, effective mass
- Electrical transport properties, piezoresistive effect
- Charge carrier concentration and mobility, Hall method, CV method
- Optical absorption, Fourier transform spectroscopy
- Impurities and defects, chemical analysis, deep traps
- Minority carrier lifetime, diffusion length
- Metal-semiconductor junction, Schottky contact, Ohmic contact, sheet resistance
- Oxide layers, ellipsometry
- Device characteristics

Objective qualification

After completing the module semiconductor characterization, the students will have

- a basic understanding of the most important methods for characterizing semiconductor materials
- the ability to select appropriate quality control procedures in the manufacture of semiconductor devices
- 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

Literature

K. Kopitzki: Einführung in die Festköperphysik (Teubner, Stuttgart, 1989) ISBN: 3-519-13083-1
H. Alexander: Physikalische Grundlagen der Elektronenmikroskopie (Teubner, Stuttgart, 1997) ISBN: 3-519-03221-X
W. Prost: Technologie der III/V-Halbleiter: III/V-Heterostrukturen und elektronische Höchstfrequenz-Bauelemente
(Springer, Berlin, 1997) ISBN:3-540-62804-5
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.

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

	2,0	Lecture	german
Literature			
K. Kopitzki: Einführung in die Festköperphysik (Teubner, Stuttgart, 1989) H. Alexander: Physikalische Grundlagen der Elektronenmikroskopie (Teubner, Stuttgart, 1997) W. Prost: Technologie der III/V-Halbleiter: III/V-Heterostrukturen und elektronische Höchstfrequenz-Bauelemente (Springer, Berlin, 1997) W. Schäfer, G. Terlecki: Halbleiterprüfung (Hüthig, Heidelberg, 1986) D. K. Schroder: Semiconductor Material and Device Characterization (Wiley, New York, 1990) R. Wiesendanger (Hrsg): Scanning Probe Microscopy - Analytical Methods (Springer, Berlin, 1998)			

	1,0	Exercise	german
Literature			
Übungsunterlagen und Vorlesungsskript werden verteilt.			

Title	Semiconductor Sensors		
Number	2413340	**Module version**	
Shorttext	ET-IHT-34	**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/ Type of examination	oral exam (30 min)		
Course achievement			

Contents

- 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
- 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
- Surface micromachining: diffusion, oxidation, layer deposition, lithography, wet/dry etching, sticking, integration with CMOS
- Volume micromachining: implantation/diffusion, metallization (evaporation/cathode sputtering), isotropic/anisotropic etching, electrochemical etching
- Epi-micromachining: Epi-poly, conformal deposition, SIMPLE, SCREAM, black silicon, SOI, electrochemical etching, porous silicon, hetero-micromachining, comparison
- Condition monitoring: machine tool, sensor/technology, roller bearings, kinematic frequencies, bogie bearing, signal analysis (envelope/resonant), calender roll, EMC/ fiber-optic readout, cavitation
- 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
- Micro/nano metrology

Objective qualification

After completing the module semiconductor sensors, the students will have
- a basic understanding of the most important methods for modelling, fabrication and characterization of micro-/nano-mechanical semiconductor sensors
- the ability to select suitable manufacturing processes for the realization of micro- and nano-structured semiconductor sensors
- in-depth knowledge and practical experience in designing sensors
- knowledge for assessing and evaluating possible uses of micro-/nano-mechanical sensors

Literature
A. Heuberger (Hrsg): Mikromechanik (Springer, Berlin, 1989) ISBN: 3-540-18721-9 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 M. Elwenspoek, R. Wiegerink: Mechanical Microsensors (Springer, Berlin, 2001) ISBN: 3-540-67582-5 E. Peiner: Silizium-Sensorik für die Maschinenüberwachung (Shaker, Aachen 2000) ISBN: 3-8265-7401-X Skript und Übungsunterlagen werden verteilt.

↑

Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	2,0	Lecture	german
Literature			
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)			
	1,0	Exercise	german
Literature			
Übungsunterlagen und Vorlesungsskript werden verteilt.			

Title	Nano- and Bioelectronic System		
Number	2413560	**Module version**	
Shorttext	ET-IHT-56	**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
growth, nanostructuring and characterization processes and tools (lithography, microscopy, raster probe technique, spectroscopy, nanotubes, nanowires, nanoparticles, hybrid nanostructures
bio-organic functionalization of surfaces (Langmuir-Blodgett, self-assembled monolayers on metals and semiconductors)
semiconductor nano- and biosensors based on different inorganic and organic nanomaterials
hybrid nanostructures for optoelectronics

Objective qualification

After completion of the module Nano- and Bioelectronic Systems, the students possess
- 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)
- 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
"Springer Handbook of Nanotechnology", B. Bhushan (Ed.), Springer, 2nd. Ed. (2006): ISBN-13: 978-3540298557

Remark

primarily master module

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

	2,0	Lecture	german
Literature			
"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
Literature			
"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	ET-IHT-58	**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/ Type of examination	oral exam (30 minutes) or written exam (120 minutes), depending on number of participants		
Course achievement	Presentation		

Contents

Basic laser technology
generation of ultrashort laser pulses
characterization of laser beams and laser pulses
spectroscopy with sub-nanosecond time resolution
basics of nonlinear optics
light-matter interaction
laser-based material processing of semiconductors
modern spectroscopy methods in semidonductor 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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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	Statistics, Design of Experiments, Optimization		
Number	2415480	Module version	
Shorttext	ET-IHF-48	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:
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

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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	ET-IEMV-12	**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
Hours per Week / ECTS	3 / 5,0	**Module owner**	Dr. Harald Spieker
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

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices #
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference #
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection #
- Legal basis, product liability, standardization #
- EMC test engineering #
- Electromagnetic compatibility of biological systems

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

- Lecture notes
- Joachim Franz, EMV – Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

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

Title	Electromagnetic Compatibility with Seminar		
Number	2419130	**Module version**	
Shorttext	ET-IEMV-13	**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
Hours per Week / ECTS	5 / 6,0	**Module owner**	
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

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection
- Legal basis, product liability, standardization
- EMC test engineering
- Electromagnetic compatibility of biological systems
- Current EMC issues presented in seminar talks

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

- continuously updated script handout
- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

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Related courses

Rules for the choice of courses

You can either choose Electromagnetic Compatibility with Seminar **or** Electromagnetic Compatibility (without seminar). The seminar can also be attened in the summer semester after having attended the EMC lecture.

Compulsory attendance

Name of the course	SWS	Eventtype	Language
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	ET-HTEE-59	**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	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			

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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	ET-NT-48	**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/ Type of examination	Written exam (120 minutes) or oral exam (30 minutes)		
Course achievement			

Contents

- Discrete-time signals and systems #
- Fourier transforms #
- Z-transforms and applications #
- Discrete-time IIR filter design #
- Discrete-time FIR filter design #
- Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT) #
- Basics of multi-rate processing and filter banks

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

- Lecture notes
- A.V. Oppenheim, R.W. Schafer, J.R. Buck: "Zeitdiskrete Signalverarbeitung" , Pearson Verlag, 2004
- K.D. Kammeyer, K. Kroschel: "Digitale Signalverarbeitung" , Teubner Verlag, 2002
- A.V. Oppenheim, R.W. Schafer, J.R. Buck: "Discrete Time Signal Processing" , Prentice-Hall, 2004
- H.-W. Schüßler: "Digitale Signalverarbeitung 1" , Springer Verlag, 1994

Remark

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

	2,0	Lecture	german
Literature			
• A. V. Oppenheim, R. W. Schafer, J. R. Buck: Zeitdiskrete Signalverarbeitung, Pearson Studium, 2004 • K. D. Kammeyer, K. Kroschel: Digitale Signalverarbeitung, Teubner Verlag, 2002 • A. V. Oppenheim, R. W. Schafer, J. R. Buck: Discrete Time Signal Processing, Prentice Hall, 2004 • H.-W. Schüßler: Digitale Signalverarbeitung, Springer Verlag, 1994			

	1,0	Exercise	german
Literature			
siehe Vorlesung			

Title	Microwave and Wireless Metrology		
Number	2424530	**Module version**	
Shorttext	ET-NT-53	**Language**	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 (30 min)		
Course achievement			

Contents

- Introduction to metrology
- Fundamentals of high-frequency technology
- Measurements in the time domain
- Spectrum analysis
- Vector network analysis
- Antenna measurement technology
- Channel measurements
- Protocol measurement technology

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

- Slides
- C.Rauscher: Grundlagen der Spektrumanalyse, Rohde & Schwarz, 2004
- M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde & Schwarz, 2007
- A.Molisch: Wireless Communications, Wiley, 2005

Remark

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

	2,0	Lecture	german
Literature			
- Foliensammlung - C.Rauscher: Grundlagen der Spektrumanalyse, Rohde & Schwarz, 2004 - M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde & Schwarz, 2007 - A.Molisch: Wireless Communications, Wiley, 2005			

	2,0	Exercise	german
Literature			
- Foliensammlung - C.Rauscher: Grundlagen der Spektrumanalyse, Rohde & Schwarz, 2004 - M.Hiebel: Grundlagen der vektoriellen Netzwerkanalyse, Rohde & Schwarz, 2007 - A.Molisch: Wireless Communications, Wiley, 2005			

Title	Applied Quantum Computing: Basics and Devices		
Number	2413620	**Module version**	
Shorttext	ET-IHT-62	**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

- Basics of Quantum Mechanics
- From Bit to Qubit
- Quantum Circuits I
- Quantum Circuits II
- Entanglement and Teleportation
- Algorithms of Quantum Computing
- Quantum Hardware I
- Quantum Hardware II

Objective qualification

- The students can name the prerequisites for the realization of qubits as well as typical platforms and explain their significance.
- Students will be able to name the strengths and weaknesses of different hardware platforms in common application scenarios and weigh them against each other.
- 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.
- Students will be able to use an exemplary platform to explain how selected quantum gates can be realized.

Literature

[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019
[2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010
[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019
[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018
[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
Applied Quantum Computing: Basics and Devices	2,0	Lecture	german
Literature			
[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019 [2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010 [3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019 [4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018 [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	ET-IDA-01	**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

- Introduction to computer architecture
- Principles of computer architecture (control, pipelining, memory hierarchy)
- Microprocessors (RISC, ISC)
- Quantitative computer design
- Design of instruction sets

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 #
W. Stallings, Computer Organization & Architecture, 6. Edition, Prentice Hall, ISBN-13: 978-0-13-035119-7 #
Lecture notes

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
	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/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

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:

- Physical principles of LEDs. Band gap engineering in LEDs.
- Semiconductor materials for optoelectronics
- Relationship between material properties and LED properties
- Manufacturing processes
- Efficiency considerations
- Front-end and back-end processing
- Application examples in general lighting, automotive technology, sensor technology
- Infrared LEDs, visible light, UV LEDs

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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
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/ 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 2. Oberflächenphysik des Festkörpers, M. Henzler und W. Göpel, Teubner Studienbücher, 1994 3. Oberflächenphysik, Grundlagen und Methoden, T. Fauster, L. Hammer, K. Heinz, und M.A. Schneider, Oldenbourg Verlag München, 2013 4. Scanning Probe Microscopy and Spectroscopy, R. Wiesendanger, Cambridge University Press, 1994 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

Literature

1. Physics at Surfaces, A. Zangwill, Cambridge University Press, 1988
2. Oberflächenphysik des Festkörpers, M. Henzler und W. Göpel, Teubner Studienbücher, 1994
3. Oberflächenphysik, Grundlagen und Methoden, T. Fauster, L. Hammer, K. Heinz, und M.A. Schneider, Oldenbourg Verlag München, 2013
4. Aktuelle Publikationen

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/ 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

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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:

- Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010
- Horowitz & Hill: The Art of Electronics (2nd ed), CUP, 1989

Supplementary:

- Pallás-Areny & Webster: Analog Signal Processing, Wiley, 1999
- MIT OCW readings & lecture notes from MAS#836 Sensor Technologies
- Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Sensor Technology	2,0	Lecture	english

Literature

Core Texts:

- Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010
- Horowitz & Hill: The Art of Electronics (2nd ed), CUP, 1989

Supplementary:

- Pallás-Areny & Webster: Analog Signal Processing, Wiley, 1999
- MIT OCW readings & lecture notes from MAS#836 Sensor Technologies
- Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)

Name of the course	SWS	Eventtype	Language
Sensor Technology	1,0	Exercise	english

Literature

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	ET-EMG-16	**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

- Characteristics of measuring sensors
- Temperature measurement
- Magnetic field measurement
- Optical sensors
- Measurement of geometric quantities
- Measurement of dynamometric quantities
- Flow measurement

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

- P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag), ISBN 978-3486225921
- H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart), ISBN 978-3519061250
- J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag), ISBN 978-3540622314 ?#8226? J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig), ISBN 978-3446219779

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

	2,0	Lecture	german
Literature			
P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag) H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart) J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag) J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)			

	2,0	Exercise	german
Literature			
P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag) H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart) J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag) J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)			

	3,0	Laboratory	german
Literature			
P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag) H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart) J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag) J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)			

Title	Automated Road Vehicles: from Assistance to Autonomy		
Number	2412620	**Module version**	
Shorttext	ET-IFR-62	**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

-probabilistic knowledge representation for driver assistance and vehicle guidance systems
- radar-based and visual machine perception
- machine situation detection and behavioural decision-making
- human-machine-interaction
- design and test of driver assistance and vehicle guidance systems

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

- 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

Remark

The course “Automotive Systems Engineering” provides helpful background knowledge for this course; however, it is not a mandatory prerequisite for participation.

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Related courses			
Rules for the choice of courses			
Only one of the three modules ET-IFR-42, ET-IFR-58, ET-IFR-62 can be chosen.			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Lecture	german
Literature			
- 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 - R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111 - M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964 - S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics			

	2,0	Exercise	german
Literature			
- 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 - R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111 - M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964 - S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics			

Title	Advanced Computer Architecture		
Number	2416520	Module version	
Shorttext	ET-IDA-52	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. Selma Saidi
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ 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 - 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	ET-NT-69	**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/ Type of examination	Oral exam 30 min. or written exam 90 min.		
Course achievement			

Contents

- Bayesian decision rule
- Quality metrics in pattern recognition
- Supervised learning with parametric distributions
- Supervised learning with non-parametric distributions, classification
- Linear discriminant functions, single-layer perceptron
- Support vector machines (SVMs)
- Multi-layer perceptron, neural networks (NNs)
- Deep learning
- Unsupervised learning, clustering methods

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.

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

- R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001
- C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006

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

	2,0	Lecture	english german
Literature			
- R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001 - C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006			

	2,0	Seminar	english german
Literature			
- Vorlesungsfolien - R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001 - C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006			

Major Specialisation: Autonomous Intelligent Systems - Elective Modules

Title	Sensors with Lab		
Number	2411160	**Module version**	
Shorttext	ET-EMG-16	**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

- Characteristics of measuring sensors
- Temperature measurement
- Magnetic field measurement
- Optical sensors
- Measurement of geometric quantities
- Measurement of dynamometric quantities
- Flow measurement

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

- P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag), ISBN 978-3486225921
- H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart), ISBN 978-3519061250
- J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag), ISBN 978-3540622314 ?#8226? J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig), ISBN 978-3446219779

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

	2,0	Lecture	german
Literature			
P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag) H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart) J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag) J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)			

	2,0	Exercise	german
Literature			
P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag) H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart) J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag) J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)			

	3,0	Laboratory	german
Literature			
P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag) H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart) J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag) J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)			

Title	Precision Measuring Techniques		
Number	2411210	**Module version**	
Shorttext	ET-EMG-21	**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/ Type of examination	oral exam (30 min); written exam (120 min) only in case of large numbers of participants		
Course achievement			

Contents

- Measuring at physical limits
- Fundamentals of quantum effects and construction of precision devices
- Electrical and magnetic properties of Josephson elements,
- SQUIDs (Superconducting Quantum Interference Devices), SETs (Single Electron Tunnelling),
- Cryogenic current comparators and quantised resistors
- Accurate DC and AC voltage sources
- Measurement of small electrical voltages, currents, charges and magnetic fields
- Application examples in medicine, research and industry.

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
J. Hoffmann "Handbuch der Messtechnik", Hanser Verlag 2004, ISBN 3-446-21123-3
F. Kohlrausch "Praktische Physik" Teubner Verlag 1996, ISBN 3-519-23000-3
K. Kopitzki "Einführung in die Festkörperphysik" Teubner-Verlag 2007, ISBN 3-835-10144-7
W. Buckel und R. Kleiner "Supraleitung", Wiley-VCH Verlag, Weinheim, 2004, ISBN 3-527-40348-5
Further literature will be announced during the lecture

Remark

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

	2,0	Lecture	german
Literature			
Wird in der Vorlesung bekannt gegeben			

	1,0	Exercise	german

Title	Quality Assurance and Optimization		
Number	2411220	**Module version**	
Shorttext	ET-EMG-22	**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
Systematic and random measurement uncertainties/errors Noise and noise analysis
Determination of measurement uncertainty according to GUM
Fundamentals of applied statistics: distribution functions, estimation theory, hypothesis tests, error propagation
Equalisation calculation, regression analysis
Statistical design of experiments
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
- W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall 1991), ISBN 978-0023805523
- O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag 1978), ISBN 978-3411001194
- N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons 1977), ISBN 978-0471017561 und 978-0471017578
- Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig 1974, im Bibliotheksbestand
- 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

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

	2,0	Lecture	german

Literature

- #E. Schrüfer: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall)
- O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag)
- N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons)
- Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig
- B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH)
- G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)

	2,0	Exercise	german

Literature

- #E. Schrüfer: Elektrische Messtechnik (Hanser Verlag)# W. Mendenhall: Statistics for Engineering and the Sciences (Prentice Hall)
- O. Hein: Statistische Verfahren der Ingenieurpraxis (B.I.-Wissenschaftsverlag)
- N. L. Johnson and F. C. Leone: Statistics and Experimental Design, Vol. 1+2 (John Wiley & Sons)
- Hartmann, Lezki und Schäfer, Statistische Versuchsplanung und -auswertung in der Stoffwirtschaft, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig
- B. Pesch: Bestimmung der Messunsicherheit nach GUM (Books on Demand GmbH)
- G. Linß: Qualitätsmanagement für Ingenieure (Fachbuchverlag Leipzig)

Title	Digital Signal Processing with Microcontrollers		
Number	2411260	**Module version**	
Shorttext	ET-EMG-26	**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/ 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,
Interpolation of measurement data,
Signal analysis: discrete (DFT) and fast (FFT) Fourier transformation
z-transform: digital filters, correlation, simulation of a closed control loop,
Controller and controlled system as IIR and FIR filters.
Assembly language of microprocessors
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
- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984, ISBN 978-3519001416
- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985, ISBN 978-3486298451
- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979, ISBN 978-3486245288
- 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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Lecture	german

Literature

- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984
- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985
- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979
- Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983

	1,0	Exercise	german

Literature

- Weber, H.: Laplace Transformation, Teubner Verlag, Stuttgart, 1984
- Doetsch, G.: Anleitung zum praktischen Gebrauch der Laplace-Transformation und der z-Transformation, Oldenbourg Verlag, München, Wien, 1985
- Stearns, S.D.: Digitale Verarbeitung analoger Signale, Oldenbourg Verlag, München, Wien, 1979
- Birk, H.; Swik, R.: Mikroprozessoren und Mikrorechner und ihre Anwendung in der Automatisierungstechnik, Oldenbourg Verlag, München, Wien, 1983

Title	Automation Engineering		
Number	2412280	**Module version**	
Shorttext	MB-VuA-22	**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:
- Aim of automation engineering
- Basics, tasks and methods of automation
- Coupling and hierarchies of systems
- Information and information management
- Control, modularization and standardization in automation
- Digitalization for industrial internet, industrial could and CPS
- Basics of knowledge management, industrial big data and decision support

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

- Lunze, J.: Automatisierungstechnik. 5. Auflage. DeGruyter (2020)
- Plenk,V.: Grundlagen der Automatisierungstechnik kompakt, Springer (2019)
- Lai, C.: Intelligent Manufacturing, Springer (2022)
- LangmannN, 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)

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

Title	Robust Control Design		
Number	2412440	**Module version**	
Shorttext	ET-IFR-44	**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/ 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, µ-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 - K. Zhou, J. C. Doyle: Robust and Optimal Control, ISBN: 978-0134565675 - K. Zhou, J. C. Doyle: Essentials of Robust Control, Prentice-Hall, ISBN: 978-0135258330
Remark
Requirement: Lecture "Fundamentals of Control Engineering"

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Related courses			
Rules for the choice of courses			
German			
Compulsory attendance			
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	ET-IFR-48	**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

- Product development process of vehicles
- Automotive electrics and electronics including requirements and standards
- Hardware architecture of electronic vehicle systems
- Electrical energy in the vehicle
- Wiring system, design criteria, wiring system architecture and development process
- Electronic systems in the powertrain
- Alternative energy sources and drive concepts
- Chassis control

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

- Folien zur Vorlesung - Bosch: Autoelektrik Autoelektronik, Vieweg Verlag
- M. Krüger: Grundlagen der Kraftfahrzeugelektronik, Hanser Verlag
- J. Schäuffele, T. Zurawka: Automotive Software Engineering, Vieweg Verlag
- Bosch: Sicherheits- und Komfortsysteme, Vieweg Verlag

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Related courses			
Rules for the choice of courses			
German			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	1,0	Exercise	german
	2,0	Lecture	german
Literature			
- Folien zur Vorlesung - Bosch: Autoelektrik Autoelektronik, Vieweg Verlag - M. Krüger: Grundlagen der Kraftfahrzeugelektronik, Hanser Verlag - J. Schäuffele, T. Zurawka: Automotive Software Engineering, Vieweg Verlag			

Title	Postgraduate Seminar Vehicle Electronics		
Number	2412510	Module version	
Shorttext	ET-IFR-51	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.

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
	2,0	Lecture	german
	0,0	Project	german

Title	Design of Digital Control Systems with MATLAB		
Number	2412560	Module version	
Shorttext	ET-IFR-56	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/ Type of examination	Written exam (60 min) or oral exam (30 min)		
Course achievement			

Contents
Dynamic state estimation: Probability theory and distribution functions, system descriptions, filtering and smoothing, Kalman and particle filters Nonlinear optimization methods: 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

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

Title	Advanced Topics in Automotive Systems Engineering		
Number	2412590	**Module version**	
Shorttext	ET-EMG-28	**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

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Related courses

Rules for the choice of courses

Compulsory attendance

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	ET-IFR-62	**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

-probabilistic knowledge representation for driver assistance and vehicle guidance systems
- radar-based and visual machine perception
- machine situation detection and behavioural decision-making
- human-machine-interaction
- design and test of driver assistance and vehicle guidance systems

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

- 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

Remark

The course “Automotive Systems Engineering” provides helpful background knowledge for this course; however, it is not a mandatory prerequisite for participation.

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Related courses			
Rules for the choice of courses			
Only one of the three modules ET-IFR-42, ET-IFR-58, ET-IFR-62 can be chosen.			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Lecture	german
Literature			
- 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 - R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111 - M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964 - S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics			

	2,0	Exercise	german
Literature			
- 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 - R. Bishop. Intelligent Vehicle Technology and Trends, Artech House, Boston, 2005, ISBN: 978-1580539111 - M. Maurer, C. Stiller. Fahrerassistenzsysteme mit maschineller Wahrnehmung, Springer, Heidelberg, 2005, ISBN: 978-3540232964 - S. Thrun, W. Burgard, D. Fox. Probabilistic Robotics			

Title	High-Voltage Safety in the Motor Vehicle		
Number	2412650	**Module version**	
Shorttext	ET-IFR-65	**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

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".

Objective qualification

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.
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.

Literature

- Folien zum Seminarinhalt
- Arbeitsblätter
- Gesetzliche Unterlagen wie:
- DGUV Information 200-005 (bisherige Bezeichnung: BGI/GUV-l 8686)
- ECE R 100
- DGUV Regel 103-011 (bisherige Bezeichnung: BGR A3)

Remark

Compulsory attendance at the seminar:
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.

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.

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

Title	Nonlinear Control Systems		
Number	2412670	**Module version**	
Shorttext	ET-IFR-46	**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.
With the help of Lyapunov's stability theory, students are able to describe the rest positions of non-linear systems and assess their stability.
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.
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.
limit cycles.
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
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"

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

Title	Control of Electrical Devices		
Number	2412680	**Module version**	
Shorttext	ET-IFR-68	**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, asychronous 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
- W. Leonhard: Control of elektrical Drives, Springer-Verlag, ISBN: 978-3540418207

Remark

Requirements: Lecture „Fundamentals of control technologies“

↑

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

Title	Semiconductor Sensors		
Number	2413340	**Module version**	
Shorttext	ET-IHT-34	**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/ Type of examination	oral exam (30 min)		
Course achievement			

Contents

- 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
- 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
- Surface micromachining: diffusion, oxidation, layer deposition, lithography, wet/dry etching, sticking, integration with CMOS
- Volume micromachining: implantation/diffusion, metallization (evaporation/cathode sputtering), isotropic/anisotropic etching, electrochemical etching
- Epi-micromachining: Epi-poly, conformal deposition, SIMPLE, SCREAM, black silicon, SOI, electrochemical etching, porous silicon, hetero-micromachining, comparison
- Condition monitoring: machine tool, sensor/technology, roller bearings, kinematic frequencies, bogie bearing, signal analysis (envelope/resonant), calender roll, EMC/ fiber-optic readout, cavitation
- 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
- Micro/nano metrology

Objective qualification

After completing the module semiconductor sensors, the students will have
- a basic understanding of the most important methods for modelling, fabrication and characterization of micro-/nano-mechanical semiconductor sensors
- the ability to select suitable manufacturing processes for the realization of micro- and nano-structured semiconductor sensors
- in-depth knowledge and practical experience in designing sensors
- knowledge for assessing and evaluating possible uses of micro-/nano-mechanical sensors

Literature
A. Heuberger (Hrsg): Mikromechanik (Springer, Berlin, 1989) ISBN: 3-540-18721-9 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 M. Elwenspoek, R. Wiegerink: Mechanical Microsensors (Springer, Berlin, 2001) ISBN: 3-540-67582-5 E. Peiner: Silizium-Sensorik für die Maschinenüberwachung (Shaker, Aachen 2000) ISBN: 3-8265-7401-X Skript und Übungsunterlagen werden verteilt.

↑

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

	2,0	Lecture	german
Literature			
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)			

	1,0	Exercise	german
Literature			
Übungsunterlagen und Vorlesungsskript werden verteilt.			

Title	Design of Electrical Machines		
Number	2414200	**Module version**	
Shorttext	ET-IMAB-20	**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/ Type of examination	Written exam (120 min) or oral exam (30 min)		
Course achievement			

Contents

- Force and torque buildup in electrical machines
- Winding design of rotating field machines
- Winding factor calculation
- Fundamentals of thermal modelling of electrical machines
- Cooling mechanisms
- Finite element methods for electromagnetic machine design
- Analytical design of electrical machines
- Motor topologies for automotive and aviation applications

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
G. Müller, B. Ponick: Theorie elektrischer Maschinen, VCH
H.O. Seinsch, Ausgleichsvorgänge bei elektrischen Antrieben, Teubner Verlag, Stuttgart

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

	2,0	Lecture	german
Literature			
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	ET-IMAB-22	**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/ 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
Reif, Noreikat, Bergeest, Kraftfahrzeug-Hybridantriebe, Springer

↑

Related courses

Rules for the choice of courses

Compulsory attendance

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	ET-IHF-34	**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

- 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)
- basic antenna structures, characteristic parameters of antennas
- array antennas and beamforming, synthesis of antenna patterns
- aperture antennas, Fourier transformation, horn and slot antennas, parabolic antennas, Physical Optics
- wave propagation, diffraction limit of free-space propagation, static models, radar cross section
- antenna and RCS characterization methods
- modern state of the art and current research topics

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
Unger, Elektromagnetische Theorie für die Hochfrequenztechnik, Hüthig-Verlag, ISBN 377851573X
Pozar, Microwave Engineering, Wiley, ASIN B001QA4I9C

Remark

Prerequisites: Mathematics, Electromagnetic Fields, Fundamentals of Information Technology, Guided Electromagnetic Waves

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
Antennas and Electromagnetic Radiation	1,0	Exercise	german
	3,0	Lecture	german

Title	Radar Systems and Signal Processing		
Number	2415450	Module version	
Shorttext	Radar-Syst	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/ Type of examination	oral exam (30 min) or written exam (60 min) or project work		
Course achievement			

Contents

Objective qualification

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.
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.

Literature

Remark

Requirements: it is recommended to have completed the module “RF and Microwave Systems and Circuits”
expected knowledge:
- introduction to RF circuits (S parameters, concept of matching)
- transmission line theory
- antenna and radio transmission basics (dipole antenna, antenna parameters, Friis transmission equation, link budget)

↑

Related courses

Rules for the choice of courses

Compulsory attendance

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

Title	Computer Architecture 2 - Embedded Systems		
Number	2416060	Module version	
Shorttext	ET-IDA-06	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	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	oral exam (30 minutes)		
Course achievement			

Contents

Specification of digital systems (FSM, statecharts, SDF, ...)

Architectural principles for embedded systems, examples (microcontrollers, digital signal processors)

Implementation:
- Automated circuit synthesis
- Optimising compilers for embedded architectures
- Scheduling in real-time operating systems

Objective qualification

Students will gain an in-depth understanding of the architecture and design of embedded systems. The focus is on formal fundamentals, systematic contexts, algorithms and methods. After completing the module, students will be able to model a given application and specify an adapted computer architecture by means of a hardware-software co-design.

Literature

#- lecture notes
- W. Wolf, Computers As Components
- Principles of Embedded Computing System Design, Morgan Kaufmann Publishers, ISBN 978-0123743978

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
	3,0	Lecture	german
	1,0	Exercise	german

Title	Advanced Computer Architecture		
Number	2416520	Module version	
Shorttext	ET-IDA-52	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. Selma Saidi
Workload (h)	150		
Class attendance (h)	42	Self studying (h)	108
Compulsory requirements			
Expected performance/ 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 - 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	ET-IDA-53	**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

- Mathematical foundations of cryptology and information security
- Functions of public and secret key cryptology
- Authentication and data security protocols
- Current applications and standards of IP network security
- Current applications and standards of wireless network security
- Network commerce and payment systems
- Selected current advanced network security topics

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.
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

- W. Adi, lecture notes and exercises
- William Stallings, Network Security Essentials: Applications and Standards, 3rd Edition, Prentice Hall, © 2007, ISBN-10: 0-13-238033-1
- Charlie Kaufman, Radia Perlman, Mike Speciner, Network Security: Private Communication in a Public World (2nd edition), Prentice Hall, 2002, ISBN-10: 0130460192

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

	2,0	Lecture	german

Literature

- W. Adi, Vorlesungsfolien und Übungen. William Stallings, Network Security Essentials: Applications and Standards, 3rd Edition, Prentice Hall, © 2007, ISBN-10: 0-13-238033-1
- Charlie Kaufman, Radia Perlman, Mike Speciner, Network Security: Private Communication in a Public World (2nd edition), Prentice Hall, 2002, ISBN-10: 0130460192

	1,0	Exercise	german

Title	Computer Architecture Basics and Lab		
Number	2416620	Module version	
Shorttext	ET-IDA-62	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/ Type of examination	Written exam (120 minutes) or oral exam (30 Minutes)		
Course achievement	Lab course		

Contents

Introduction to computer architecture
Principles of computer architecture (control, pipelining, memory hierarchy)
Microprocessors (RISC, ISC)
Quantitative computer design and design of instruction sets
Practical experiments in the following areas
Metrological investigation of line effects and synchronisation methods
Assembler and automaton implementation on microcontrollers
Circuit design using hardware design languages
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.
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
- The Hardware/Software Interface, 3rd edition, David A. Patterson and John L. Hennessy
- Lecture / lab notes

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	1,0	Exercise	german
	4,0	Internship	german
	3,0	Lecture	german

Title	Embedded Computing Systems with Lab		
Number	2416640	**Module version**	
Shorttext	ET-IDA-64	**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/ Type of examination			
Course achievement			
Contents			
Introduction to computer architecture Principles of computer architecture (control, pipelining, memory hierarchy) Microprocessors (RISC, ISC) Quantitative computer design and design of instruction sets Practical experiments from the following areas Construction of an Application Specific Instruction Set Processor (ASIP) Hardware design with a hardware description language (VHDL) Programming / extension of the software for the ASIP (C) Hardware / software co-design 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. 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			

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	3,0	Lecture	german
	1,0	Exercise	german
	4,0	Internship	german
Literature			
Skript			

Title	Network-Security		
Number	2416770	**Module version**	
Shorttext	ET-IDA-77	**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

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Lecture	german

Literature

Material provided to students in StudIP, including the references noted within

	1,0	Exercise	german

Literature

Material provided to students in StudIP, including the references noted within

Title	Advanced Topics in Real-Time Embedded Operating Systems		
Number	2416800	Module version	
Shorttext	ET-IDA-06	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

- Requirements, design constraints and tradeoffs for real-time embedded systems
- Relevant aspects of operating systems (Multi-Threading, Multi-Core, Synchronization, Mixed-Criticality)
- Relevant aspects of real-time systems (Execution model, scheduling, resource sharing)
- optional: industrial perspective on embedded real-time systems
- overview on existing operating systems for embedded real-time applications
- Schedulability Analysis
- Student talks on topic releated papers

Objective qualification

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, suich as the abilities to present and critically review scientific publications.

Literature

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

Title	Electromagnetic Compatibility		
Number	2419120	**Module version**	
Shorttext	ET-IEMV-12	**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
Hours per Week / ECTS	3 / 5,0	**Module owner**	Dr. Harald Spieker
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

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices #
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference #
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection #
- Legal basis, product liability, standardization #
- EMC test engineering #
- Electromagnetic compatibility of biological systems

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

- Lecture notes
- Joachim Franz, EMV – Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

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

Title	Electromagnetic Compatibility with Seminar		
Number	2419130	**Module version**	
Shorttext	ET-IEMV-13	**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
Hours per Week / ECTS	5 / 6,0	**Module owner**	
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

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection
- Legal basis, product liability, standardization
- EMC test engineering
- Electromagnetic compatibility of biological systems
- Current EMC issues presented in seminar talks

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

- continuously updated script handout
- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

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Related courses

Rules for the choice of courses

You can either choose Electromagnetic Compatibility with Seminar **or** Electromagnetic Compatibility (without seminar). The seminar can also be attened in the summer semester after having attended the EMC lecture.

Compulsory attendance

Name of the course	SWS	Eventtype	Language
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	ET-BST-14	**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

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.

The lecture is divided into the following chapters:

- High-frequency amplifier circuits
- Simulation of electronic noise
- Low-noise input amplifiers in CMOS
- Mixer circuits
- HPhase-locked loops (PLLs)
- Voltage-controlled oscillators

Objective qualification

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).

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.
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

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

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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	ET-BST-15	**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

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.

The lecture is divided into the following chapters:
- High frequency amplifier circuits
- Simulation of electronic noise
- Low-noise input amplifiers in CMOS
- Mixer circuits
- Phase-locked loops (PLLs)
- Voltage-controlled oscillators

Objective qualification

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).

Literature

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

↑

Related courses

Rules for the choice of courses

Prerequisite for this module: Circuit Design (ST)

Compulsory attendance

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

Title	Electrical Railways		
Number	2423430	**Module version**	
Shorttext	ET-HTEE-43	**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/ Type of examination	oral exam (30 min)		
Course achievement			

Contents

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.
are also considered.
0 . Repetitorium: Fundamentals of electrical engineering and electrical power engineering for electric railways
1 Introduction: Classification of railway vehicles and electric road bus systems
2. national and international stationary traction current systems, DC and AC
3. electric drives
- Historical development of drive topologies
- Inverter systems
- Drive control
- Traction motors and mechanical drive configurations
- Internal combustion vehicles/power transmission types
4. auxiliary systems
- Heating, air conditioning and ventilation
- Batteries, local grid feeds
- Auxiliary converter topologies
5. signalling and security systems
- Overview of the most important systems used in Europe
- On-board equipment
6. control technology on railway vehicles
- Tasks: Control and diagnostics
- Train and vehicle buses and their components
7. passenger information and multimedia
8 Vehicles operated
TRAXX, EuroSprinter, ICE 3, LIREX, ET 423, regional urban railway Regio CITADIS for Kassel, LINT
9. future developments
Fuel cell, electronic transformer, gearless direct drive, hybrid vehicles, contactless energy transmission energy transmission
10. electric road bus systems (trolleybus, battery bus with inductive/conductive charging)

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

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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	ET-NT-50	**Language**	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. Tim Fingscheidt
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 (90 min) (according to number of participants)		
Course achievement	Colloquium or laboratory protocol as proof of performance		

Contents

- Speech production
- Speech perception
- Linear prediction and speech modelling
- Speech coding
- Noise reduction
- Acoustic echo compensation

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

- Copies of lecture slides
- P.Vary u. R.Martin: Digital Speech Transmission, Wiley 2006

Remark

This module of the Master’s programme is also suited for Bachelor students.
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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

	2,0	Lecture	german
Literature			
Kopien der Vorlesungsfolien P.Vary u. R.Martin: Digital Speech Transmission, Wiley 2006			

	2,0	Laboratory	german
Literature			
siehe Vorlesung			

Title	Advanced Seminar "Machine Learning"		
Number	2424600	Module version	
Shorttext	ET-IFR-42	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. 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.

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

	2,0	Lecture	german
Literature			
Literatur wird im Seminar ausgegeben.			

	0,0	Project	german
Literature			
Literatur wird im Seminar ausgegeben.			

Title	Spoken Language Processing		
Number	2424680	**Module version**	
Shorttext	ET-NT-68	**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

- Basics of speech production and perception
- Feature extraction
- Hidden Markov models
- Acoustic models and language models
- Automatic speech recognition
- Spoken language systems

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

- Lecture slides
- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001
- B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008
- A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004
- E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995
- G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003
- L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993
- K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990

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

	2,0	Lecture	english
Literature			
- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001 - B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008 - A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004 - E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995 - G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003 - L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993 - K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990			

	2,0	Seminar	english
Literature			
- X. Huang, A. Acero, H.-W. Hon: Spoken Language Processing, Prentice Hall, 2001 - B. Pfister, T. Kaufmann: Sprachverarbeitung, Springer, 2008 - A. Wendemuth: Grundlagen der Stochastischen Sprachverarbeitung, Oldenbourg, 2004 - E.G. Schukat-Talamazzini: Automatische Spracherkennung, Vieweg, 1995 - G.A. Fink: Mustererkennung mit Markov-Modellen, Teubner, 2003 - L. Rabiner, B.-H. Juang: Fundamentals of Speech Recognition, Prentice Hall, 1993 - K. Fukunaga: Statistical Pattern Recognition, Academic Press, 1990			

Title	Pattern Recognition		
Number	2424690	**Module version**	
Shorttext	ET-NT-69	**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/ Type of examination	Oral exam 30 min. or written exam 90 min.		
Course achievement			

Contents

- Bayesian decision rule
- Quality metrics in pattern recognition
- Supervised learning with parametric distributions
- Supervised learning with non-parametric distributions, classification
- Linear discriminant functions, single-layer perceptron
- Support vector machines (SVMs)
- Multi-layer perceptron, neural networks (NNs)
- Deep learning
- Unsupervised learning, clustering methods

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.

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

- R.O. Duda, P.E. Hart, D.G. Stork: Pattern Classification, Wiley, 2001
- C.M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006

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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
	2,0	Lecture	english german
Literature			
- R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001 - C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006			
	2,0	Seminar	english german
Literature			
- Vorlesungsfolien - R. O. Duda, P. E. Hart, D. G. Stork: Pattern Classification, Wiley, 2001 - C. M. Bishop: Pattern Recognition and Machine Learning, Springer, 2006			

Title	Electromagnetic Compatibility in Automotive Systems		
Number	2497050	**Module version**	
Shorttext	ET-IFR-50	**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

- Electromagnetic environment and protection goals in the automotive sector;
- Sources of interference and coupling mechanisms;
- EMC-compliant power supply, vehicle electrical system architecture and power types;
- Measures to ensure EMC: grounding, shielding and filtering;
- EMC development process and test methods for vehicles and components, for conducted and radiated interference and ESD;
- EMC standards in the automotive sector and statutory EMC requirements;
- Product responsibility and liability

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

- M.I. Montrose; EMC and the printed Circuit Board - Design, Theory, and Layout made simple, IEEE-Press, ISBN: 978-0780347038
- V.P. Kodali; Engineering Electromagnetic Compatibility - Principles, Meassurements, and Technologies, IEEE-Press, ISBN: 978-0780347434

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

	2,0	Lecture	german

Literature

- M. I. Montrose, EMC and the printed Circuit Board - Design, Theory, and Layout made simple, IEEE-Press
- V. P. Kodali; Engineering Electromagnetic Compatibility - Principles, Measurements, and Technologies, IEEE-Press

	1,0	Exercise	german

Literature

- M. I. Montrose, EMC and the printed Circuit Board - Design, Theory, and Layout made simple, IEEE-Press
- V. P. Kodali; Engineering Electromagnetic Compatibility - Principles, Measurements, and Technologies, IEEE-Press

	1,0	Excursion	german

Literature

- M.I. Montrose, EMC and the printed Circuit Board - Design, Theory, and Layout made simple, IEEE-Press, ISBN: 978-0780347038
- V.P. Kodali; Engineering Electromagnetic Compatibility - Principles, Measurements, and Technologies, IEEE-Press, ISBN: 978-0780347434

Title	Automation of Industrial Manufacturing Processes		
Number	2522610	Module version	
Shorttext	MB-IWF-61	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/ Type of examination	1 examination element: written exam (120 min) or oral exam (30 min)		
Course achievement			

Contents

- Analysis of industrial case studies and individual components (automotive industry, production of batteries and electronic components, and manufacturing processes for the aviation industry)
- Introduction to automated processes with an overview of the economic and overall significance, the definitions and technical terms
- Overview of hardware and devices used for automation
- Introduction to PLC especially regarding tasks and capabilities within automated processes
- Overview and operating principles of sensors and actuators with selected examples
- Insight into current and practical developments and their influence on the automation of industrial processes (Industry 4.0, Human-Robot-Collaboration (HRC))

Objective qualification

Students...

- 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).
- are able to classify the presented scenarios with regard to quantity, production costs and automation costs.
- 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.
- can use #Petri-Nets# to model complex process sequences in control systems.
- can use CFC programming (Continous Function Chart) to perform simple control tasks.

Literature

1. Lauber, R.; Göhner, P.: Prozessautomatisierung 2, Springer-Verlag, Berlin, Heidelberg, 1999
2. Favre-Bulle, B.: Automatisierung komplexer Industrieprozesse, Springer-Verlag, Wien, 2004
3. Gevatter H.J.: Automatisierungstechnik 2, Springer-Verlag, Berlin, Heidelberg, 2000
4. Bindel, T; Hofmann, D: Projektierung von Automatisierungsanlagen. Wiesbaden: Springer Fachmedien Wiesbaden, 2013

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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	Modelling of Mechatronic Systems		
Number	2540310	**Module version**	
Shorttext	MB-DuS-31	**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**	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

- D. A. Wells, Lagrangian Dynamics, Schaum's Outlines, 1967
- R. H. Cannon, Dynamics of Physical Systems, Mc Graw Hill, 2003
- B. Fabian, Analytical System Dynamics, Springer, 2009

Remark

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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	Computer Networks 2 (MPO 2017)		
Number	4213390	**Module version**	V2
Shorttext	INF-KM-39	**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/ Type of examination	1 graded work: Written exam (90 minutes) or oral exam (20 minutes) or Take-Home-Exam.		
Course achievement			

Contents

- Internet protocols
- IP
- TCP
- Routing methods
- Newer protocols and methods

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
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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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
	4,0	Lecture/Exercise	english

Literature

- 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

	2,0	Exercise	english

Title	Robotics 2 - Programming, Modelling, Planning		
Number	4215450	**Module version**	V2
Shorttext	INF-ROB-45	**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 beginnung 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:
- Principles of perception and measurments and robot sensing
- Techniques of modeling and simulation
- Paradigms and best practices of robot programming
- Specification of robotic tasks
- Planning method of robotic actions
- Techniques for the study of work space and singularities
- Distinction of rigid and elastic components
- Advances techniques for controlling robotic systems
- 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:
- Deepened understanding of essential, theoretical foundations of robotics
- Broadened knowledge of practical tasks for running robots
- Further pervasion of a systemic, model-based approach to robotics
- Perception of a robot as a technical system for motion and force generation
- Deepened comprehension of properties of spatial motions
- Expansion of programming competences
- Increased ability to reflect on programming activities
- 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

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
Robotics 2	2,0	Lecture	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.			
Robotics 2	2,0	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	INF-ROB-39	**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/ 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 beginnung of the lecture.		
Course achievement			

Contents

They are able to

- understand and correctly apply basic concepts of medical robotics
- model manipulators and describe them in geometrical and mathematical terms
- compute kinematic transforms
- compute and analyze the Jacobian, including singularities and redundancy
- compute differential kinematics and use these in control settings
- 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

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**

Robotics 1 - Technical and Mathematical Basics	2,0	Lecture	english german

Literature

- 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	Machine Learning and Its Application in Communications Technology		
Number	2424000000	**Module version**	
Shorttext	ET-NT-0000	**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**	Prof. Dr. Eduard Jorswieck
Workload (h)	180		
Class attendance (h)	42	**Self studying (h)**	138
Compulsory requirements			
Expected performance/ Type of examination			
Course achievement			

Contents

- Introduction of basic ideas of neural networks
- Introduction of the basic neural network architecture as well as loss function, gradient descent and optimizer for neural network training
- Setting up a development environment for machine learning with Python and Pytorch
- Hands-on experiment of defining and training of a simple deep neural network
- Introduction of advanced neural network architectures, including convolutional neural network, recurrent neural network, graph neural network and transformers. Understanding why they were invented and how they work
- Introduction of dedicated objective function for unsupervised learning in communications engineering
- Introduction of dedicated neural network architectures for unsupervised learning in communications engineering

Objective qualification

The students
- know the basics of neural network models
- understands the training process with massive data for supervised learning
- can generalize from supervised learning to unsupervised learning
- can implement and train the neural network model with Python and Pytorch for simple tasks
- understands how to consider domain knowledge of communications engineering in designing the neural network architecture and objective
- can optimize the training process if the outcome is not as expected

Literature

Y. C. Eldar, A. Goldsmith, D. Gündüz, H. V. Poor, Machine Learning and Wireless Communications, Cambridge University Press, 2022.
http://cs231n.stanford.edu/2019/

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

Machine learning and its application in communications technology	2,0	Lecture	german
Literature			
Y. C. Eldar, A. Goldsmith, D. Gündüz, H. V. Poor, Machine Learning and Wireless Communications, Cambridge University Press, 2022. http://cs231n.stanford.edu/2019/			

Machine learning and its application in communications technology	1,0	Exercise	german
Literature			
Y. C. Eldar, A. Goldsmith, D. Gündüz, H. V. Poor, Machine Learning and Wireless Communications, Cambridge University Press, 2022. http://cs231n.stanford.edu/2019/			

Title	Computer Architecture 1		
Number	2416010	**Module version**	
Shorttext	ET-IDA-01	**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

- Introduction to computer architecture
- Principles of computer architecture (control, pipelining, memory hierarchy)
- Microprocessors (RISC, ISC)
- Quantitative computer design
- Design of instruction sets

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 #
W. Stallings, Computer Organization & Architecture, 6. Edition, Prentice Hall, ISBN-13: 978-0-13-035119-7 #
Lecture notes

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
	1,0	Exercise	german
	3,0	Lecture	german

Title	Low power CMOS data converter circuit design		
Number	2420210	**Module version**	
Shorttext	ET-BST-21	**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

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.

General introduction of data converters
1. Data converter application areas
Sensor interface, Communication (wireless/wireline)
2. Basic theory in data conversion
Sampling/Quantization, Performance metric (INL/DNL, SNDR, SFDR, ENOB, FoM)
3. Architectures and features of data converters
2-1. High resolution data converter (SAR, ##, VCO based)
2-2. High speed data converter (Flash, Pipeline)

Implementation of low-power and high-resolution CMOS integrated ADCs
4. Building blocks of ADC
Comparator, operational amplifier
5. SAR-ADC with charge redistribution.
3-1. Power reduction techniques
3-2. Resolution enhancement techniques (digital calibration etc.)
6. High resolution ## modulator
7. Time based (VCO based) ADC
8. Hybrid-ADC
9. Characterization of data converters

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/ Type of examination	Written (90 min) or oral exam (30 min)		
Course achievement			

Contents

- 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.
- 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++.

Objective qualification

The students
- gain an understanding of specific requirements, issues, and performance evaluations of low-power embedded system applications.
- make design decisions with deep knowledge of the inherent cost-versus-performance trade-offs in low-power, resource-constrained systems.
- apply the principles of real-time operating systems and scheduling theory to design efficient applications with shared resources.
- 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.

Literature

- 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.
- P. Marwedel: Embedded System Design, Springer, ISBN 978- 3-030-60909-2, 2021.
- G.C. Buttazzo: Hard Real- Time Computing Systems. Springer Verlag, ISBN 978- 1-4614-0676-1, 2011.
- M. Wolf: Computers as Components – Principles of Embedded System Design. Morgan Kaufman Publishers, ISBN 978-0-128-05387-4, 2016.
- Avelino J. Gonzalez: Computer Programming in C for Beginners, Springer, ISBN 978-3-030-50752-7, 2020.

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

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Low-Power Embedded Systems	2,0	Lecture	english

Literature

- 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.
- P. Marwedel: Embedded System Design, Springer, ISBN 978- 3-030-60909-2, 2021.
- G. C. Buttazzo: Hard Real-Time Computing Systems. Springer Verlag, ISBN 978- 1-4614-0676-1, 2011.
- M. Wolf: Computers as Components – Principles of Embedded System Design. Morgan Kaufman Publishers, ISBN 978-0-128-05387-4, 2016.
- Avelino J. Gonzalez: Computer Programming in C for Beginners, Springer, ISBN 978-3-030-50752-7, 2020.
- Joseph Yiu. The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors. Newnes, 2013.

Name of the course	SWS	Eventtype	Language
Low-Power Embedded Systems	1,0	Exercise	english

Literature

- 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.
- P. Marwedel: Embedded System Design, Springer, ISBN 978- 3-030-60909-2, 2021.
- G. C. Buttazzo: Hard Real-Time Computing Systems. Springer Verlag, ISBN 978- 1-4614-0676-1, 2011.
- M. Wolf: Computers as Components – Principles of Embedded System Design. Morgan Kaufman Publishers, ISBN 978-0-128-05387-4, 2016.
- Avelino J. Gonzalez: Computer Programming in C for Beginners, Springer, ISBN 978-3-030-50752-7, 2020.
- Joseph Yiu. The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors. Newnes, 2013.

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 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	Basic knowlesge of computer architectures and programming language C		
Expected performance/ Type of examination	1. Written exam (max 180 min) or oral exam (max 40 min) 2. Project work incl. written reports 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
2. Understanding of design components
3. Understanding of system-level design paradigms
4. HW/SW partitioning
5. Optimization methods
6. Performance analysis measures
7. Evaluation methods
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
[2] „Digitale Hardware/Software Systeme – Synthese und Optimierung", J. Teich, Springer Verlag 1997, ISBN 3-540-62433-3

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
Hardware Software Codesign	3,0	Lecture	english

Literature

[1] „Specification and Design of Embedded Systems", D. Gajski, Prentice Hall 1994,
ISBN 0-13-150731-1
[2] „Digitale Hardware/Software Systeme – Synthese und Optimierung", J. Teich,
Springer Verlag 1997, ISBN 3-540-62433-3

Name of the course	**SWS**	**Eventtype**	**Language**
Hardware Software Codesign	1,0	Exercise	english

Literature

[1] „Specification and Design of Embedded Systems", D. Gajski, Prentice Hall 1994,
ISBN 0-13-150731-1
[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/ Type of examination	1. Written exam (max 90 min) or oral exam (max 30 min) 2. Project work incl. written reports The overall grade is the arithmetic average of the grades of components 1 and 2.		
Course achievement			

Contents

- Requirements on functional safety
- Providing and preserving trustworthiness in Autonomous Systems
- System Architectures and Platforms for Autonomous Systems
- Verification of Autonomous Systems

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.
Samuel Kounev, Jeffrey O. Kephart, Aleksandar Milenkoski, and Xiaoyun Zhu: „Self-Aware Computing Systems”. Springer Publishing Company, Incorporated, 1st edition, 2017.
Defense Advanced Research Projects Agency (DARPA). Broad Agency Announcement - Assured Autonomy, August 2017
Selma Saidi, Dirk Ziegenbein, Jyotirmoy V. Deshmukh, Rolf Ernst: “Autonomous Systems Design: Charting a New Discipline”, IEEE Design and Test Magazine 2021.

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
Embedded Autonomy	3,0	Lecture	english

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.
Samuel Kounev, Jeffrey O. Kephart, Aleksandar Milenkoski, and Xiaoyun Zhu: „Self-Aware Computing Systems”. Springer Publishing Company, Incorporated, 1st edition, 2017.
Defense Advanced Research Projects Agency (DARPA). Broad Agency Announcement - Assured Autonomy, August 2017
Selma Saidi, Dirk Ziegenbein, Jyotirmoy V. Deshmukh, Rolf Ernst: “Autonomous Systems Design: Charting a New Discipline”, IEEE Design and Test Magazine 2021.

Embedded Autonomy	1,0	Exercise	english

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.
Samuel Kounev, Jeffrey O. Kephart, Aleksandar Milenkoski, and Xiaoyun Zhu: „Self-Aware Computing Systems”. Springer Publishing Company, Incorporated, 1st edition, 2017.
Defense Advanced Research Projects Agency (DARPA). Broad Agency Announcement - Assured Autonomy, August 2017
Selma Saidi, Dirk Ziegenbein, Jyotirmoy V. Deshmukh, Rolf Ernst: “Autonomous Systems Design: Charting a New Discipline”, IEEE Design and Test Magazine 2021.

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: 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%) b) Compulsory course achievement: colloquium or report (organized in groups) on the completed laboratory experiments		

Contents

Lecture/Tutorial:
- Aim of automation engineering
- Basics, tasks and methods of automation
- Coupling and hierarchies of systems
- Information and information management
- Control, modularization and standardization in automation
- Digitalization for industrial internet, industrial could and CPS
- Basics of knowledge management, industrial big data and decision support

Laboratory:
- Computer-aided design of an automation system
- Realization of an automation task with a PLC
- Modelling and simulation of robots
- Robot programming
- NC programming - production of a turned part
- Control of an automated guided vehicle (AGV)

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);
- LangmannN, 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/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

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:

- Physical principles of LEDs. Band gap engineering in LEDs.
- Semiconductor materials for optoelectronics
- Relationship between material properties and LED properties
- Manufacturing processes
- Efficiency considerations
- Front-end and back-end processing
- Application examples in general lighting, automotive technology, sensor technology
- Infrared LEDs, visible light, UV LEDs

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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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Gallium Nitride Technology	2,0	Lecture	german
Gallium Nitride Technology	1,0	Exercise	german

Title	Industrial Robots with Laboratory		
Number	2522560	Module version	
Shorttext	MB-IWF-56	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

- Introduction: History, groups of robots, fields of apply
- Structure-development: degrees of freedom, joints, serial and parallel structures, structure of a robot
- Programming: Types of programming, languages of programming (especially KRL)
- Kinematic: Elementary-transformation, kinematic robot-model, types of calculation, singularities
- Dynamic and bearing-control: dynamic robot model, calculation of forces and moments, types of bearing-control
- Control: Creation of movement, structure, sensor integration

Objective qualification

Students...
- have the ability to differentiate between serial and parallel structures and to divide the robot into main and secondary axes.
- are able to analyze workspaces and designs and will be able to evaluate them with regard to application criteria.
- will be able to explain components of the robot.
- are able to explain and calculate kinematic and dynamic models of different robots.
- 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.
- are able to identify structure-specific problems and develop solution strategies.
- can place themselves in a group, contribute to the solution and present the results.

Literature

- Lenarcic, J.; Parenti V.: Advances in Robot Kinematics 2018. Springer, Berlin, 2018
- Appleton, E.; Williams, D. J.: Industrieroboter: Anwendungen. VCH: Weinheim, New York, Basel, Cambridge, 1991
- Knoll, A.; Christaller, T.: Robotik. Fischer, Frankfurt, November 2003
- Siciliano, B.; Khatib, O.: Springer Handbook of Robotics, Springer Verlag, Berlin, 2008
- Volmer, J.: Industrieroboter - Funktion und Gestaltung. Verl. Technik: Berlin, 1992

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

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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
	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

- Foundation Models

- Prompt Engineering

- Retrieval-Augmented Generation

- Agents

- Finetuning

- Legal and Ethical Aspects

- Building Applications with Foundation Models

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

- Lecure slides

- Publications on key technologies

- C. Huyen: „AI Engineering“, O‘Reilly Media, 2025

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

AI Engineering	2,0	Lecture	english
Literature			
- Vorlesungsfolien - Publikationen zu Schlüsseltechnologien - C. Huyen: „AI Engineering“, O‘Reilly Media, 2025			

Computer Lab AI Engineering	2,0	Internship	english
Literature			
- Lecure slides - Publications on key technologies - C. Huyen: „AI Engineering“, O‘Reilly Media, 2025			

Title	Verification, Validation and Testing of ASIC Designs		
Number	4211500	**Module version**	
Shorttext	INF-EIS-50	**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/ 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.

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Verification, Validation and Testing of ASIC Designs	4,0	Lecture/Exercise	english

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" Weitere Referenzen werden in der Veranstaltung bekannt gegeben.

Title	Memory Systems		
Number	4211460	**Module version**	V2
Shorttext	INF-EIS-46	**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)
2. Overview on Memory Technology
2.1 Volatile Memories: SRAM, DRAM
2.2 Non-volatile Memories: ROM, Flash Memory, F-RAM, MRAM,...
3. Main Memory: Interfaces, Commands, and Controllers
4. Memory Cache
5. Processing-in-Memory (PIM) / New Data Processing
5.1 Using traditional and 3D-Stacked memories
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
• Hennessy and Patterson (2017): "Computer Architecture. A Quantitative Approach", 6th Edition, Morgan Kaufmann
• Jacob, Ng, and Wang (2008): "Memory Systems: Cache, DRAM, Disk", Morgan Kaufmann "

Further references will be announced in the course.

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

Memory Systems	2,0	Lecture	english
Literature			
- Balasubramonian (2019): "Innovations in the Memory Systems", Morgen & Claypool Publishers - Hennessy and Patterson (2017): "Computer Architecture. A Quantitative Approach", 6th Edition, Morgan Kaufmann - Jacob, Ng, and Wang (2008): "Memory Systems: Cache, DRAM, Disk", Morgan Kaufmann " Further references will be announced in the course.			

Memory Systems	2,0	Exercise	english

Title	Advanced FPGA-Design		
Number	4211510	**Module version**	V2
Shorttext	INF-EIS-51	**Language**	english german
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/ 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
2. FPGA Basic Architecture (incl. DSP blocks, embedded memories, soft and hard processors) (Review)
3. Additional Architectural Elements of FPGAs (Boundary scan, I/O cells (PLLs), MIG, transceivers, analog-to-digital converters, ...)
4. FPGA Memory Technologies (SRAM, EPROM, Flash, Anti-Fuse, MRAM)
5. High-Performance Circuit Design on FPGAs
6. Dynamic and Partial Reconfiguration Mechanisms (incl. Space-Time FPGAs)
7. Design Tools for FPGAs (incl. VTR)
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

- 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

Further references will be announced in the course

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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

Major Specialisation: Microelectronics Engineering - Compulsory Elective Modules

Title	Analog Integrated Circuits		
Number	2420150	**Module version**	
Shorttext	ET-BST-15	**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

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.

The lecture is divided into the following chapters:
- High frequency amplifier circuits
- Simulation of electronic noise
- Low-noise input amplifiers in CMOS
- Mixer circuits
- Phase-locked loops (PLLs)
- Voltage-controlled oscillators

Objective qualification

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).

Literature

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

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

Title	Analog RF CMOS 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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

Analog RF CMOS Integrated Circuits	2,0	Lecture	english
Literature			
Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press			

Analog RF CMOS Integrated Circuits	1,0	Exercise	english
Literature			
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/ 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

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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 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	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

- Review of the Laplace transform
- Review of Kirchhoff's laws
- Review of modified nodal analysis
- Properties and analysis of N-port networks
- Tellegen's theorem and its applications in network theory
- Foster networks and synthesis methods
- Fundamentals of graph theory for electrical networks
- Bloch-Floquet theorem for the analysis of periodic structures
- Periodicity in electrical networks and its implications
- Introduction to metamaterials and their modelling

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

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

Advanced Network Analysis	2,0	Lecture	english
Literature			
Pozar, D. M. (2011). Microwave Engineering (4th ed.). Wiley.			

Advanced Network Analysis	1,0	Exercise	english
Literature			
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/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

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:

- Physical principles of LEDs. Band gap engineering in LEDs.
- Semiconductor materials for optoelectronics
- Relationship between material properties and LED properties
- Manufacturing processes
- Efficiency considerations
- Front-end and back-end processing
- Application examples in general lighting, automotive technology, sensor technology
- Infrared LEDs, visible light, UV LEDs

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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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Gallium Nitride Technology	2,0	Lecture	german
Gallium Nitride Technology	1,0	Exercise	german

Title	Semiconductor Technology		
Number	2413420	**Module version**	
Shorttext	ET-IHT-42	**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/ Type of examination	Oral exam 30 min		
Course achievement			

Contents

- physical and chemical basics
- manufacturing of single crystals and wafers
- epitaxial crystal growth processes and crystal defects
- doping processes
- semiconductor measurement technology
- planar technology
- basics of photolithography, deposition processes for dielectrics and etching processes

Objective qualification

After completing the semiconductor technology module, students have:

- an understanding of the basic manufacturing technologies of semiconductors as well as components and integrated circuits made from them.
- the ability to recognize the principles of the most modern manufacturing processes in semiconductor technology and their modes of operation
- the ability to analyze and extrapolate trends in semiconductor technology developments

Literature

- Lecture transparencies
- Script in Englisch (H.-H. Wehmann and A. Schlachetzki)
- Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(Stuttgart, 1998) ISBN: 3-519-06167-8
- Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (Berlin, 1991) ISBN: 3-540-53873-9
- Werner Prost: Technologie der III/V-Halbleiter, Springer (Berlin, 1997) ISBN. 3-540-62804-5
- Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (Stuttgart, 2004) ISBN: 3-519-30149-0

Remark

Language German or English

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

Title	Integrated Circuits for Biomedical Applications		
Number	2420190	**Module version**	
Shorttext	ET-BST-19	**Language**	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/ Type of examination	Oral exam (30 min) or written exam (90 min)		
Course achievement			

Contents

- Introduction to biomedical applications
- Biosensing principles (physical, electrical and electrochemical)
- Basic biomedical circuits: transimpedance and instrumentation amplifiers, oscillators, ADCs/DACs
- Basic circuits for Power Management (DCDC, LDO, Rectifier)
- Self-powering and energy storage (e.g. biofuel cell sensing, energy harvesting)
- Wireless Power Transfer (WPT) for implantable devices
- Circuits for ultra-low power data transmission
- Circuits for electrochemical sensing (potentiometric and amperometric)
- Examples of potentiometric biosensors (pH, K+, Na+, Ca+ etc) and iontophoresis
- Circuits for Impedance Spectroscopy
- Radar-based Imaging for Breast Cancer Detection
- Circuits for Electrical Impedance Tomography
- Resonance-based dielectric sensors (e.g. for glucose detection)
- Circuits for cochlear implants

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
“Power Management Integrated Circuits (Devices, Circuits, and Systems)”, M. Hella, P. Mercier, CRC Press, 2016
“Introduction to Biosensors From Electric Circuits to Immunosensors”, J.-Y. Yoon, Springer 2016

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
	2,0	Lecture	german

Literature

?Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems?, Rahul Sarpeshkar, Cambridge University Press, 2010 ?Power Management Integrated Circuits (Devices, Circuits, and Systems)?, M. Hella, P. Mercier, CRC Press, 2016 ?Introduction to Biosensors From Electric Circuits to Immunosensors?, J.-Y. Yoon, Springer 2016

	2,0	Exercise	german

Literature

?Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems?, Rahul Sarpeshkar, Cambridge University Press, 2010 ?Power Management Integrated Circuits (Devices, Circuits, and Systems)?, M. Hella, P. Mercier, CRC Press, 2016 ?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:

- Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010
- Horowitz & Hill: The Art of Electronics (2nd ed), CUP, 1989

Supplementary:

- Pallás-Areny & Webster: Analog Signal Processing, Wiley, 1999
- MIT OCW readings & lecture notes from MAS#836 Sensor Technologies
- Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
Sensor Technology	2,0	Lecture	english

Literature

Core Texts:

- Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010
- Horowitz & Hill: The Art of Electronics (2nd ed), CUP, 1989

Supplementary:

- Pallás-Areny & Webster: Analog Signal Processing, Wiley, 1999
- MIT OCW readings & lecture notes from MAS#836 Sensor Technologies
- Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)

Sensor Technology	1,0	Exercise	english

Literature

Project and sensor type-specific; s. lecture for literature and provided articles.

Major Specialisation: Microelectronics Engineering - Elective Modules

Title			
Number	4211510	**Module version**	
Shorttext	INF-EIS-51	**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/ Type of examination	1 graded work: Written exam (90 minutes) or oral exam (30 minutes)		
Course achievement			

Contents

1. Introduction to Reconfigurable Computing
2. FPGA Basic Architecture (incl. DSP blocks, embedded memories, soft and hard processors) (Review)
3. Additional Architectural Elements of FPGAs (Boundary scan, I/O cells (PLLs), MIG, transceivers, analog-to-digital converters, ...)
4. FPGA Memory Technologies (SRAM, EPROM, Flash, Anti-Fuse, MRAM)
5. High-Performance Circuit Design on FPGAs
6. Dynamic and Partial Reconfiguration Mechanisms (incl. Space-Time FPGAs)
7. Design Tools for FPGAs (incl. VTR)
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

- 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

Further references will be announced in the course

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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	Analog RF CMOS 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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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

Analog RF CMOS Integrated Circuits	2,0	Lecture	english
Literature			
Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press			

Analog RF CMOS Integrated Circuits	1,0	Exercise	english
Literature			
Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press			

Title	Analog Integrated Circuits		
Number	2420150	**Module version**	
Shorttext	ET-BST-15	**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

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.

The lecture is divided into the following chapters:
- High frequency amplifier circuits
- Simulation of electronic noise
- Low-noise input amplifiers in CMOS
- Mixer circuits
- Phase-locked loops (PLLs)
- Voltage-controlled oscillators

Objective qualification

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).

Literature

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

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Related courses

Rules for the choice of courses

Prerequisite for this module: Circuit Design (ST)

Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
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/ 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

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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	ET-IMAB-23	**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

- Power electronics and electromagnetic compatibility (EMC)
- EMC guidelines and filter circuits
- Power Factor Correction (PFC)
- Resonant power converters
- Quasi-resonant circuits
- Multi-level converters

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
Applikationshandbuch Leistungshalbleiter, Semikron, ISLE-Verlag

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

	2,0	Lecture	german
Literature			
- Skript - DIN 41750: "Begriffe für Stromrichter", Beuth Verlag GmbH, 1984 - Jötten, R.: "Leistungselektronik", Vieweg Verlag, Braunschweig, 1977 - Heumann/Stumpe: "Thyristoren", Teubner Verlag, Stuttgart, 1970			

	2,0	Exercise	german

Title	Applied Quantum Computing: Basics and Devices		
Number	2413620	**Module version**	
Shorttext	ET-IHT-62	**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

- Basics of Quantum Mechanics
- From Bit to Qubit
- Quantum Circuits I
- Quantum Circuits II
- Entanglement and Teleportation
- Algorithms of Quantum Computing
- Quantum Hardware I
- Quantum Hardware II

Objective qualification

- The students can name the prerequisites for the realization of qubits as well as typical platforms and explain their significance.
- Students will be able to name the strengths and weaknesses of different hardware platforms in common application scenarios and weigh them against each other.
- 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.
- Students will be able to use an exemplary platform to explain how selected quantum gates can be realized.

Literature

[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019
[2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010
[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019
[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018
[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019

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

Applied Quantum Computing: Basics and Devices	2,0	Lecture	german
Literature			
[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019 [2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010 [3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019 [4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018 [5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019			

Applied Quantum Computing: Basics and Devices	1,0	Exercise	german

Title	Packaging and Interconnection Technology		
Number	2413390	**Module version**	
Shorttext	ET-IHT-39	**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

- Open wiring, bread board, printed circuit board
- Thick film technologies, substrates, screen printing and pastes, thin film technology, photolithography
- Surface mount technology, components, housing forms, modern developments (TAB, BGA, flip chip, CSP, MCM)
- Power modules, special requirements
- Cooling, basics and problems, air cooling, liquid cooling
- Thermomechanical stresses and reliability, basics, examples
- Soldering
- Adhesive bonding
- Wire bonding
- Direct copper bonding
- Low-temperature joining technology

Objective qualification

After completing the module electronic packaging, the students will have
- a basic understanding of the most important processes for assembling and joining electronic devices and components
- the ability to select suitable processes for packaging in the manufacture of semiconductor modules
- in-depth knowledge and practical experience in the use, analysis and evaluation of methods of electronic packaging

Literature

W. Scheel (Hrsg.): Baugruppentechnologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) ISBN: 3-341-01100-5
H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01097-1
H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Hybridträger (Verlag Technik, Berlin, Saulgau, 1994) ISBN: 3-341-01099-8
M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiesbaden, 1991) ISBN: 3-528-06392-0

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

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course	**SWS**	**Eventtype**	**Language**
	1,0	Exercise	german
Literature			
Unterlagen werden verteilt.			

	2,0	Lecture	german
Literature			
W. Scheel (Hrsg.): Baugruppentechnologie der Elektronik - Montage (Verlag Technik, Berlin; Eugen G. Lenze Verlag, Saulgau, 1997) H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Leiterplatten (Verlag Technik, Berlin, Saulgau, 1994) H.-J. Hanke (Hrsg.): Baugruppentechnologie der Elektronik # Hybridträger (Verlag Technik, Berlin, Saulgau, 1994) M. Wutz: Wärmeabfuhr in der Elektronik (Vieweg, Wiebaden, 1991)			

Title	Introduction to Logic Circuits		
Number	2420000070	Module version	
Shorttext		Language	
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

- Introduction to CMOS
- Basic Logic Circuits
- Layout of digital CMOS circuits
- Optimization and weighting of the stages
- Delay definitions
- Flip-Flops in standard CMOS logic
- TSPC logic
- C2MOS logic
- CML logic
- Sensitivity curves and speed optimization techniques

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

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
Introduction to Logic Circuit	2,0	Lecture	english
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			
Introduction to Logic Circuit	2,0	Exercise	english
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			

Title	Advanced Network Analysis		
Number	2420000050	**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	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

- Review of the Laplace transform
- Review of Kirchhoff's laws
- Review of modified nodal analysis
- Properties and analysis of N-port networks
- Tellegen's theorem and its applications in network theory
- Foster networks and synthesis methods
- Fundamentals of graph theory for electrical networks
- Bloch-Floquet theorem for the analysis of periodic structures
- Periodicity in electrical networks and its implications
- Introduction to metamaterials and their modelling

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

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Advanced Network Analysis	2,0	Lecture	english
Literature			
Pozar, D. M. (2011). Microwave Engineering (4th ed.). Wiley.			
Advanced Network Analysis	1,0	Exercise	english
Literature			
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/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			

Contents

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:

- Physical principles of LEDs. Band gap engineering in LEDs.
- Semiconductor materials for optoelectronics
- Relationship between material properties and LED properties
- Manufacturing processes
- Efficiency considerations
- Front-end and back-end processing
- Application examples in general lighting, automotive technology, sensor technology
- Infrared LEDs, visible light, UV LEDs

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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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Gallium Nitride Technology	2,0	Lecture	german
Gallium Nitride Technology	1,0	Exercise	german

Title	Fundamentals of Nano Optics		
Number	1520430	Module version	
Shorttext	PHY-AP-43	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 cristals, plasmonics)
2. Production and characterisation (metrology) of nano structures
3. Photonic nano materials / meta materials / meta surfaces
4. Optic nano emitters and nano antennae
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.
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.
Participants are able to identify the basic elements in complex optical systems and describe their respective functions.
The participants can name important processes of micro- and nanostructuring and explain how they work.
The participants can solve the wave equation in simple dielectric, metallic and hybrid nanooptical systems analytically and semi-analytically and interpret the solutions.
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
Prasad: Nanophotonics, John Wiley & Sons 2004
Jahns, Helfert: Introduction to Micro- and Nanooptics, Wiley VCH 2012

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Fundamentals of Nano Optics	2,0	Lecture	english
Fundamentals of Nano Optics	1,0	Exercise	english

Title	Semiconductor Technology		
Number	2413420	**Module version**	
Shorttext	ET-IHT-42	**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/ Type of examination	Oral exam 30 min		
Course achievement			

Contents

- physical and chemical basics
- manufacturing of single crystals and wafers
- epitaxial crystal growth processes and crystal defects
- doping processes
- semiconductor measurement technology
- planar technology
- basics of photolithography, deposition processes for dielectrics and etching processes

Objective qualification

After completing the semiconductor technology module, students have:
- an understanding of the basic manufacturing technologies of semiconductors as well as components and integrated circuits made from them.
- the ability to recognize the principles of the most modern manufacturing processes in semiconductor technology and their modes of operation
- the ability to analyze and extrapolate trends in semiconductor technology developments

Literature

- Lecture transparencies
- Script in Englisch (H.-H. Wehmann and A. Schlachetzki)
- Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(Stuttgart, 1998) ISBN: 3-519-06167-8
- Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (Berlin, 1991) ISBN: 3-540-53873-9
- Werner Prost: Technologie der III/V-Halbleiter, Springer (Berlin, 1997) ISBN. 3-540-62804-5
- Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (Stuttgart, 2004) ISBN: 3-519-30149-0

Remark

Language German or English

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

Semiconductor Technology	2,0	Lecture	english
Literature			
Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(1998) Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (1991) Werner Prost: Technologie der III/V-Halbleiter, Springer (1997) Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (2004) Ausführliches Skript in Englisch Vorlesungsfolien			

Semiconductor Technology	1,0	Exercise	english
Literature			
Übungsmaterial wird verteilt.			

Title	Integrated Circuits for Biomedical Applications		
Number	2420190	**Module version**	
Shorttext	ET-BST-19	**Language**	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/ Type of examination	Oral exam (30 min) or written exam (90 min)		
Course achievement			

Contents

- Introduction to biomedical applications
- Biosensing principles (physical, electrical and electrochemical)
- Basic biomedical circuits: transimpedance and instrumentation amplifiers, oscillators, ADCs/DACs
- Basic circuits for Power Management (DCDC, LDO, Rectifier)
- Self-powering and energy storage (e.g. biofuel cell sensing, energy harvesting)
- Wireless Power Transfer (WPT) for implantable devices
- Circuits for ultra-low power data transmission
- Circuits for electrochemical sensing (potentiometric and amperometric)
- Examples of potentiometric biosensors (pH, K+, Na+, Ca+ etc) and iontophoresis
- Circuits for Impedance Spectroscopy
- Radar-based Imaging for Breast Cancer Detection
- Circuits for Electrical Impedance Tomography
- Resonance-based dielectric sensors (e.g. for glucose detection)
- Circuits for cochlear implants

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
“Power Management Integrated Circuits (Devices, Circuits, and Systems)”, M. Hella, P. Mercier, CRC Press, 2016
“Introduction to Biosensors From Electric Circuits to Immunosensors”, J.-Y. Yoon, Springer 2016

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

	2,0	Lecture	german
Literature			
?Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems?, Rahul Sarpeshkar, Cambridge University Press, 2010 ?Power Management Integrated Circuits (Devices, Circuits, and Systems)?, M. Hella, P. Mercier, CRC Press, 2016 ?Introduction to Biosensors From Electric Circuits to Immunosensors?, J.-Y. Yoon, Springer 2016			

	2,0	Exercise	german
Literature			
?Ultra Low Power Bioelectronics, Fundamentals, Biomedical Applications, and Bio-Inspired Systems?, Rahul Sarpeshkar, Cambridge University Press, 2010 ?Power Management Integrated Circuits (Devices, Circuits, and Systems)?, M. Hella, P. Mercier, CRC Press, 2016 ?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, Anlog 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

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.

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.

Objective qualification

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.

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

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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/ Type of examination	Oral exam (30 min)		
Course achievement			

Contents

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.

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.

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

- Neuromorphic Computing for Computer Scientists
- Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601
- Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. https://www.nature.com/articles/s41928-023-01053-4
- C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 https://www.nature.com/articles/s43588-021-00184-y

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

Neuromorphic Computing & Engineering	2,0	Lecture	english
Literature			
• Neuromorphic Computing for Computer Scientists • Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601 • Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. https://www.nature.com/articles/s41928-023-01053-4 • C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 https://www.nature.com/articles/s43588-021-00184-y			

Neuromorphic Computing & Engineering	1,0	Exercise	english
Literature			
• Neuromorphic Computing for Computer Scientists • Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601 • Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. https://www.nature.com/articles/s41928-023-01053-4 • C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 https://www.nature.com/articles/s43588-021-00184-y			

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

- System overview
- Jitter and phase noise
- Basic PLL architectures
- Analog integer PLL
- Digital integer PLL
- Fractional PLL
- Clock data recovery
- Delay locked loop
- Numerically controlled oscillator
- Software PLL

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
Behzad Razavi “Design of CMOS Phase-Locked Loops: From Circuit Level to Architecture Level”, Cambridge University Press, 2020

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

Phase-Locked Loops and Frequency Synthesis	2,0	Lecture	english
Literature			
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
Literature			
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:

- Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010
- Horowitz & Hill: The Art of Electronics (2nd ed), CUP, 1989

Supplementary:

- Pallás-Areny & Webster: Analog Signal Processing, Wiley, 1999
- MIT OCW readings & lecture notes from MAS#836 Sensor Technologies
- Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)

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Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course	SWS	Eventtype	Language
Sensor Technology	2,0	Lecture	english

Literature

Core Texts:

- Fraden, J.: Handbook of Modern Sensors (4th ed), Springer, 2010
- Horowitz & Hill: The Art of Electronics (2nd ed), CUP, 1989

Supplementary:

- Pallás-Areny & Webster: Analog Signal Processing, Wiley, 1999
- MIT OCW readings & lecture notes from MAS#836 Sensor Technologies
- Recent journal papers on MEMS sensors, bio#sensors (assigned weekly)

Name of the course	SWS	Eventtype	Language
Sensor Technology	1,0	Exercise	english

Literature

Project and sensor type-specific; s. lecture for literature and provided articles.

Title			
Number	4211480	**Module version**	V2
Shorttext	INF-EIS-48	**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

- Introduction to VLSI Design
- Fundamentals of CMOS Transistors
- Fabrication and Layout of CMOS Integrated Circuits
- CMOS Circuits (Combinational and Sequential Logic Circuits)
- Design Methodologies
- Issues in Chip Design

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

- D. Harris, N. Weste: "CMOS VLSI Design.", Pearson Education, Inc (2010).
- H. Veendrick: "Nanometer CMOS ICs ", Springer, 2007
- Y. Taur, T. Ning: "Fundamentals of Modern VLSI Devices", Cambridge University Press, 1998
- J.M. Rabaey, A. P. Chandrakasan, and B. Nikoli#; “Digital Integrated Circuits: a Design Perspective”. Vol. 7. Upper Saddle River, NJ: Pearson Education, 2003.
- J. Uyemura: "CMOS Logic Circuit Design", Kluwer Academic Publishers, 1999
- K. Reifschneider: "CAE-gestützte IC-Entwurfsmethoden", Prentice Hall, 1998
- K. Itoh: "VLSI Memory Chip Design", Springer, 2001
- D. Jansen: "Handbuch der Electronic Design Automation", Carl Hanser Verlag, 2002
- R. J. Baker, H. W. Li, D. E. Byce: "CMOS Circuit Design. Layout, and Simulation", IEEE Press 1998
- R. Hunter, T. Johnson: "VHDL", Springer, 2007
- D. Perry: "VHDL", McGraw-Hill, 1998
- P. Ashenden: "The Designers Guide to VHDL", Morgan Kaufmann, 2002

Further references will be announced in the course.

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

Title	VLSI-Lab		
Number	4211490	**Module version**	
Shorttext	INF-EIS-49	**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

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...

Objective qualification

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

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.

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Related courses			
Rules for the choice of courses			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**
VLSI-Lab	4,0	Internship	english
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.			

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 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/ Type of examination	Oral exam (30 min)		
Course achievement			

Contents

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.

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.

Objective qualification

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.

Literature

- Neuromorphic Computing for Computer Scientists
- Shih-Chii Liu. Event-Based Neuromorphic Systems. 2014 Wiley Print ISBN:9780470018491, DOI:10.1002/9781118927601
- Z. Sun et al. A full spectrum of computing-in-memory technologies. Nature Electronics 2023, 6, 823-835. https://www.nature.com/articles/s41928-023-01053-4
- C. Schuman et al. Opportunities for neuromorphic computing algorithms and applications. Nature Computational Science 2022, 2, 10-19 https://www.nature.com/articles/s43588-021-00184-y

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

Emerging Memory Technologies	2,0	Lecture	english

Literature

- T. Schenk et al., Memory technology – a primer for material scientists. Reports on Progress in Physics, 2020, 83, 086501. https://doi.org/10.1088/1361-6633/ab8f86
- W. Zhang et al., Designing crystallization in phase- change materials for universal memory and neuro-inspired computing. Nature Reviews Materials, 2019, 4, 150. https://doi.org/10.1038/s41578-018-0076-x
- D. Lencer et al., Design Rules for Phase-Change Materials in Data Storage Applications. Advanced Materials, 2011, 23 (18), 2030. https://doi.org/10.1002/adma.201004255
- S. W. Fong et al., Phase-Change Memory – Towards a Storage-Class Memory. IEEE Transactions on Electron Devices, 2017, 64 (11), 4374. https://doi.org/10.1109/TED.2017.2746342
- S. Yuasa et al., Materials for spin-transfer-torque magnetoresistive random-access memory. MRS Bulletin, 2018, 43, 352. https://doi.org/10.1557/mrs.2018.93
- S. Ikegawa et al., Magnetoresistive Random Access Memory: Present and Future. IEEE Transactions on Electron Devices, 2020, 67 (4), 1407. https://doi.org/10.1109/TED.2020.2965403
- H.-S. Philip Wong et al., Metal-Oxide RRAM. Proceedings of the IEEE, 2012, 100 (6), 1951. https://doi.org/10.1109/JPROC.2012.2190369
- M. N. Kozicki et al., Conductive bridging random access memory – materials, devices and applications. Semiconductor Science and Technology, 2016, 31 (11), 113001. https://doi.org/10.1088/0268-1242/31/11/113001

Emerging Memory Technologies	1,0	Exercise	english

Literature

- T. Schenk et al., Memory technology – a primer for material scientists. Reports on Progress in Physics, 2020, 83, 086501. https://doi.org/10.1088/1361-6633/ab8f86
- W. Zhang et al., Designing crystallization in phase- change materials for universal memory and neuro-inspired computing. Nature Reviews Materials, 2019, 4, 150. https://doi.org/10.1038/s41578-018-0076-x
- D. Lencer et al., Design Rules for Phase-Change Materials in Data Storage Applications. Advanced Materials, 2011, 23 (18), 2030. https://doi.org/10.1002/adma.201004255
- S. W. Fong et al., Phase-Change Memory – Towards a Storage-Class Memory. IEEE Transactions on Electron Devices, 2017, 64 (11), 4374. https://doi.org/10.1109/TED.2017.2746342
- S. Yuasa et al., Materials for spin-transfer-torque magnetoresistive random-access memory. MRS Bulletin, 2018, 43, 352. https://doi.org/10.1557/mrs.2018.93
- S. Ikegawa et al., Magnetoresistive Random Access Memory: Present and Future. IEEE Transactions on Electron Devices, 2020, 67 (4), 1407. https://doi.org/10.1109/TED.2020.2965403
- H.-S. Philip Wong et al., Metal-Oxide RRAM. Proceedings of the IEEE, 2012, 100 (6), 1951. https://doi.org/10.1109/JPROC.2012.2190369
- M. N. Kozicki et al., Conductive bridging random access memory – materials, devices and applications. Semiconductor Science and Technology, 2016, 31 (11), 113001. https://doi.org/10.1088/0268-1242/31/11/113001

Laboratory Courses

Title	Lab Master Electrical Engineering		
Number	2499500	Module version	
Shorttext	ET-STDE-50	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/ 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
Literature			
Internship script			

	3,0	Laboratory	german
Literature			
P. Profos und T. Pfeiffer: Handbuch der industriellen Messtechnik (R. Oldenbourg Verlag) H. Schaumburg: Sensoren (B.G. Teubner Verlag Stuttgart) J. Hoffmann: Messen nichtelektrischer Größen (VDI Verlag) J. Hoffmann: Taschenbuch der Messtechnik (Fachbuchverlag Leipzig)			

	4,0	Laboratory	german

	3,0	Laboratory	german

	3,0	Laboratory	german
Literature			
Skript			

	3,0	Laboratory	german
Literature			
Skript zum Herunterladen.			

	3,0	Laboratory	german
Literature			
Skript			

Laboratory practical course indoor lighting	2,0	Laboratory	german
Literature			
DIN 5035-5			

	2,0	Internship	german

	2,0	Internship	german

	2,0	Internship	german

	1,0	Laboratory	english
Literature			
Skript zum Praktikum			

	4,0	Internship	german

	4,0	Internship	german

	5,0	Internship	german
Literature			
J. Liebeherr und M. El Zarki,: Mastering Networks -An Internet Lab Manual-, Pearson, 2004, ISBN: 0-201-78134-4			

	4,0	Internship	german
Literature			
J. Liebeherr und M. El Zarki,: Mastering Networks -An Internet Lab Manual-, Pearson, 2004, ISBN: 0-201-78134-4			

	2,0	Internship	german
Literature			
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
Literature			
Skript			

	4,0	Internship	german

	2,0	Internship	german

	2,0	Internship	german

	2,0	Internship	german

	2,0	Laboratory	german
Literature			
siehe Vorlesung			

	2,0	Laboratory	german
Literature			
siehe Vorlesung			

	2,0	Laboratory	german
Literature			
siehe Vorlesung			

	2,0	Laboratory	german
Literature			
siehe Vorlesung			

	2,0	Laboratory	german
Literature			
siehe Vorlesung			

	4,0	Internship	german
Literature			
Skripte (Download: https://www.tu-braunschweig.de/ifn/lehre/praktika-und-labore/skripte)			

	3,0	Laboratory	german

	4,0	Laboratory	german
Literature			
- 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
Literature			
• Book: Network of Things Engineering (NoTE) Lab • Herausgeber: # Springer; 1st ed. 2023 Edition (10. Januar 2023) • Sprache: # Englisch • Gebundene Ausgabe: # 240 Seiten • ISBN-10: # 3031206347 • ISBN-13: # 978-3031206344			

	5,0	Internship	german
Literature			
• Book: Network of Things Engineering (NoTE) Lab • Herausgeber: # Springer; 1st ed. 2023 Edition (10. Januar 2023) • Sprache: # Englisch • Gebundene Ausgabe: # 240 Seiten • ISBN-10: # 3031206347 • ISBN-13: # 978-3031206344			

Computer Lab Pattern Recognition	4,0	Laboratory	english german
Literature			
Christopher M. Bishop, Nasser M. Nasrabadi, “Pattern Recognition and Machine Learning”, Springer 2006 Ian Goodfellow, Yoshua Bengio, Aaron Courville, “Deep Learning”, MIT Press 2016			

electrotechnical laboratory practical course specialization battery technologies	3,0	Internship	german

Computer Network Engineering Lab - CNE Lab	5,0	Internship	english
Literature			
For literature, we will use the Mastering Networks book and the instructions based on it. Liebeherr, Jorg, and Magda El Zarki. Mastering Networks: An Internet Lab Manual. Addison-Wesley Longman Publishing Co., Inc., 2003.			

Network of Things Engineering Domain Lab – NoTED Lab	5,0	Internship	english
Literature			
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
Literature			
- Skript zum Praktikum - zusätzlich kann auf die vorlesungsbegleitende Literatur zurückgegriffen werden. Ergänzende Unterlagen werden während des Praktikums verteilt.			

Low-Power Embedded Systems Laboratory	5,0	Laboratory	english
Literature			
Tutorials and example code will be provided on Gitlab. Further literature: - 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. - P. Marwedel: Embedded System Design, Springer, ISBN 978- 3-030-60909-2, 2021. - G.C. Buttazzo: Hard Real- Time Computing Systems. Springer Verlag, ISBN 978- 1-4614-0676-1, 2011. - M. Wolf: Computers as Components – Principles of Embedded System Design. Morgan Kaufman Publishers, ISBN 978-0-128-05387-4, 2016. - Avelino J. Gonzalez: Computer Programming in C for Beginners, Springer, ISBN 978-3-030-50752-7, 2020. - 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
Literature			
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
Literature			
Tutorials and example codes will be provided on StudIP.			

	5,0	Internship	english german
Literature			
Tutorials and example codes will be provided on StudIP.			

Extradisciplinary Qualifications

Title	Industrial Internship		
Number	2499040	**Module version**	
Shorttext	ET-STDE-04	**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

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.
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.
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.

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.

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

Title	Master's Team Project		
Number	2499520	Module version	
Shorttext	ET-STDE-52	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			

↑

Related courses			
Rules for the choice of courses			
The Master's team project can replace the industrial internship.			
Compulsory attendance			
Name of the course	**SWS**	**Eventtype**	**Language**

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/ Type of examination			
Course achievement	according to the requirements of the course taken from the pool selection; Seminar presentation: presentation according to § 4 para. 14		

Contents
individual

Objective qualification
Key qualifications will be achieved in the following fields: - Action-oriented courses, scientific cultures 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. https://www.tu-braunschweig.de/studium-lehre/im-studium/lehrveranstaltungen 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. - Seminar lecture 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.

Literature

↑

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

Title	Master's Thesis		
Number	2499510	**Module version**	
Shorttext	ET-STDE-51	**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/ Type of examination	• Preparation of the Master's thesis (28 credits) • Presentation (according to § 4 para. 14 BPO) (2 credits) The assessment of the presentation is included in the overall grade of the final module with double weighting.		
Course achievement			

Contents

individual

Objective qualification

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:

- Independent familiarisation with and scientific methodical processing of a topic fundamentally relevant to further development and research in the field of electrical engineering
- Literature research and presentation of the state of the art
- Development of new solution approaches for a scientific problem
- Presentation of the approach and results in the form of a paper
- Presentation of the main results in a comprehensible form
- Consolidation and refinement of key qualifications: management of an own project, presentation techniques and rhetorical skills

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.

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