TUHH Hamburg University of Technology

Module Manual

Master of Science (M.Sc.)

Electrical Engineering

Cohort: Winter Term 2018

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Program description

Content

Core Qualification

Module M0523: Business & Management

Module Responsible	Prof. Matthias Meyer
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to find their way around selected special areas of management within the scope of business management. • Students are able to explain basic theories, categories, and models in selected special areas of business management. • Students are able to interrelate technical and management knowledge.
Skills	• Students are able to apply basic methods in selected areas of business management. • Students are able to explain and give reasons for decision proposals on practical issues in areas of business management.
Personal Competence	
Social Competence	• Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems
Autonomy	• Students are capable of acquiring necessary knowledge independently by means of research and preparation of material.
Workload in Hours	Depends on choice of courses
Credit points	6

Courses
Information regarding lectures and courses can be found in the corresponding module handbook published separately.

Module M0524: Nontechnical Elective Complementary Courses for Master

Module Responsible	Dagmar Richter
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	**The Nontechnical Academic Programms (NTA)** imparts skills that, in view of the TUHH's training profile, professional engineering studies require but are not able to cover fully. Self-reliance, self-management, collaboration and professional and personnel management competences. The department implements these training objectives in its **teaching architecture**, in its **teaching and learning arrangements**, in **teaching areas** and by means of teaching offerings in which students can qualify by opting for **specific competences** and a **competence level** at the Bachelor's or Master's level. The teaching offerings are pooled in two different catalogues for nontechnical complementary courses. **The Learning Architecture** consists of a cross-disciplinarily study offering. The centrally designed teaching offering ensures that courses in the nontechnical academic programms follow the specific profiling of TUHH degree courses. The learning architecture demands and trains independent educational planning as regards the individual development of competences. It also provides orientation knowledge in the form of "profiles". The subjects that can be studied in parallel throughout the student's entire study program - if need be, it can be studied in one to two semesters. In view of the adaptation problems that individuals commonly face in their first semesters after making the transition from school to university and in order to encourage individually planned semesters abroad, there is no obligation to study these subjects in one or two specific semesters during the course of studies. **Teaching and Learning Arrangements** provide for students, separated into B.Sc. and M.Sc., to learn with and from each other across semesters. The challenge of dealing with interdisciplinarity and a variety of stages of learning in courses are part of the learning architecture and are deliberately encouraged in specific courses. **Fields of Teaching** are based on research findings from the academic disciplines cultural studies, social studies, arts, historical studies, communication studies, migration studies and sustainability research, and from engineering didactics. In addition, from the winter semester 2014/15 students on all Bachelor's courses will have the opportunity to learn about business management and start-ups in a goal-oriented way. The fields of teaching are augmented by soft skills offers and a foreign language offer. Here, the focus is on encouraging goal-oriented communication skills, e.g. the skills required by outgoing engineers in international and intercultural situations. **The Competence Level** of the courses offered in this area is different as regards the basic training objective in the Bachelor's and Master's fields. These differences are reflected in the practical examples used, in content topics that refer to different professional application contexts, and in the higher scientific and theoretical level of abstraction in the B.Sc. This is also reflected in the different quality of soft skills, which relate to the different team positions and different group leadership functions of Bachelor's and Master's graduates in their future working life. **Specialized Competence (Knowledge)** Students can • explain specialized areas in context of the relevant non-technical disciplines, • outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area, • different specialist disciplines relate to their own discipline and differentiate it as well as make connections, • sketch the basic outlines of how scientific disciplines, paradigms, models, instruments, methods and forms of representation in the specialized sciences are subject to individual and socio-cultural interpretation and historicity, • Can communicate in a foreign language in a manner appropriate to the subject.
Skills	**Professional Competence (Skills)** In selected sub-areas students can • apply basic and specific methods of the said scientific disciplines, • aquestion a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline, • to handle simple and advanced questions in aforementioned scientific disciplines in a sucsessful manner, • justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject.

Personal Competence	
Social Competence	**Personal Competences (Social Skills)** Students will be able • to learn to collaborate in different manner, • to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees, • to express themselves competently, in a culturally appropriate and gender-sensitive manner in the language of the country (as far as this study-focus would be chosen), • to explain nontechnical items to auditorium with technical background knowledge.
Autonomy	**Personal Competences (Self-reliance)** Students are able in selected areas • to reflect on their own profession and professionalism in the context of real-life fields of application • to organize themselves and their own learning processes • to reflect and decide questions in front of a broad education background • to communicate a nontechnical item in a competent way in writen form or verbaly • to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)
Workload in Hours	Depends on choice of courses
Credit points	6

Courses
Information regarding lectures and courses can be found in the corresponding module handbook published separately.

Module M0676: Digital Communications

Courses

Title	Typ	Hrs/wk	CP
Digital Communications (L0444)	Lecture	2	3
Digital Communications (L0445)	Recitation Section (large)	1	2
Laboratory Digital Communications (L0646)	Practical Course	1	1

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics 1-3 • Signals and Systems • Fundamentals of Communications and Random Processes
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to understand, compare and design modern digital information transmission schemes. They are familiar with the properties of linear and non-linear digital modulation methods. They can describe distortions caused by transmission channels and design and evaluate detectors including channel estimation and equalization. They know the principles of single carrier transmission and multi-carrier transmission as well as the fundamentals of basic multiple access schemes.
Skills	The students are able to design and analyse a digital information transmission scheme including multiple access. They are able to choose a digital modulation scheme taking into account transmission rate, required bandwidth, error probability, and further signal properties. They can design an appropriate detector including channel estimation and equalization taking into account performance and complexity properties of suboptimum solutions. They are able to set parameters of a single carrier or multi carrier transmission scheme and trade the properties of both approaches against each other.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Written elaboration; **Description**
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Core Qualification: Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Computational Science and Engineering: Specialisation Kernfächer Ingenieurswissenschaften (2 Kurse): Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory

Course L0444: Digital Communications	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	• Digital modulation methods • Coherent and non-coherent detection • Channel estimation and equalization • Single-Carrier- and multi carrier transmission schemes, multiple access schemes (TDMA, FDMA, CDMA, OFDM)
Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley R.G. Gallager: Principles of Digital Communication. Cambridge A. Goldsmith: Wireless Communication. Cambridge. D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge.

Course L0445: Digital Communications	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0646: Laboratory Digital Communications	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	- DSL transmission - Random processes - Digital data transmission
Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley R.G. Gallager: Principles of Digital Communication. Cambridge A. Goldsmith: Wireless Communication. Cambridge. D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge.

Module M0746: Microsystem Engineering

Courses

Title	Typ	Hrs/wk	CP
Microsystem Engineering (L0680)	Lecture	2	4
Microsystem Engineering (L0682)	Project-/problem-based Learning	2	2

Module Responsible	Prof. Manfred Kasper
Admission Requirements	None
Recommended Previous Knowledge	Basic courses in physics, mathematics and electric engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about the most important technologies and materials of MEMS as well as their applications in sensors and actuators.
Skills	Students are able to analyze and describe the functional behaviour of MEMS components and to evaluate the potential of microsystems.
Personal Competence	
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire particular knowledge using specialized literature and to integrate and associate this knowledge with other fields.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 10 % / Presentation /
Examination	Written exam
Examination duration and scale	2h
Assignment for the Following Curricula	Electrical Engineering: Core Qualification: Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0680: Microsystem Engineering	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Manfred Kasper
Language	EN
Cycle	WiSe
Content	Object and goal of MEMS Scaling Rules Lithography Film deposition Structuring and etching Energy conversion and force generation Electromagnetic Actuators Reluctance motors Piezoelectric actuators, bi-metal-actuator Transducer principles Signal detection and signal processing Mechanical and physical sensors Acceleration sensor, pressure sensor Sensor arrays System integration Yield, test and reliability
Literature	M. Kasper: Mikrosystementwurf, Springer (2000) M. Madou: Fundamentals of Microfabrication, CRC Press (1997)

Course L0682: Microsystem Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Manfred Kasper
Language	EN
Cycle	WiSe
Content	Examples of MEMS components Layout consideration Electric, thermal and mechanical behaviour Design aspects
Literature	Wird in der Veranstaltung bekannt gegeben

Module M0710: Microwave Engineering

Courses

Title	Typ	Hrs/wk	CP
Microwave Engineering (L0573)	Lecture	2	3
Microwave Engineering (L0574)	Recitation Section (large)	2	2
Microwave Engineering (L0575)	Practical Course	1	1

Module Responsible	Prof. Arne Jacob
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of communication engineering, semiconductor devices and circuits. Basics of Wave propagation from transmission line theory and theoretical electrical engineering.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the propagation of electromagnetic waves and related phenomena. They can describe transmission systems and components. They can name different types of antennas and describe the main characteristics of antennas. They can explain noise in linear circuits, compare different circuits using characteristic numbers and select the best one for specific scenarios.
Skills	Students are able to calculate the propagation of electromagnetic waves. They can analyze complete transmission systems und configure simple receiver circuits. They can calculate the characteristic of simple antennas and arrays based on the geometry. They can calculate the noise of receivers and the signal-to-noise-ratio of transmission systems. They can apply their theoretical knowledge to the practical courses.
Personal Competence	
Social Competence	Students work together in small groups during the practical courses. Together they document, evaluate and discuss their results.
Autonomy	Students are able to relate the knowledge gained in the course to contents of previous lectures. With given instructions they can extract data needed to solve specific problems from external sources. They are able to apply their knowledge to the laboratory courses using the given instructions.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory:** Yes; **Bonus:** None; **Form:** Subject theoretical and practical work; **Description:**
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Core Qualification: Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory

Course L0573: Microwave Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	WiSe
Content	- Antennas: Analysis - Characteristics - Realizations - Radio Wave Propagation - Transmitter: Power Generation with Vacuum Tubes and Transistors - Receiver: Preamplifier - Heterodyning - Noise - Selected System Applications
Literature	H.-G. Unger, „Elektromagnetische Theorie für die Hochfrequenztechnik, Teil I", Hüthig, Heidelberg, 1988 H.-G. Unger, „Hochfrequenztechnik in Funk und Radar", Teubner, Stuttgart, 1994 E. Voges, „Hochfrequenztechnik - Teil II: Leistungsröhren, Antennen und Funkübertragung, Funk- und Radartechnik", Hüthig, Heidelberg, 1991 E. Voges, „Hochfrequenztechnik", Hüthig, Bonn, 2004 C.A. Balanis, "Antenna Theory", John Wiley and Sons, 1982 R. E. Collin, "Foundations for Microwave Engineering", McGraw-Hill, 1992 D. M. Pozar, "Microwave and RF Design of Wireless Systems", John Wiley and Sons, 2001 D. M. Pozar, "Microwave Engineerin", John Wiley and Sons, 2005

Course L0574: Microwave Engineering	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0575: Microwave Engineering	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0846: Control Systems Theory and Design

Courses

Title	Typ	Hrs/wk	CP
Control Systems Theory and Design (L0656)	Lecture	2	4
Control Systems Theory and Design (L0657)	Recitation Section (small)	2	2

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	Introduction to Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain how linear dynamic systems are represented as state space models; they can interpret the system response to initial states or external excitation as trajectories in state space • They can explain the system properties controllability and observability, and their relationship to state feedback and state estimation, respectively • They can explain the significance of a minimal realisation • They can explain observer-based state feedback and how it can be used to achieve tracking and disturbance rejection • They can extend all of the above to multi-input multi-output systems • They can explain the z-transform and its relationship with the Laplace Transform • They can explain state space models and transfer function models of discrete-time systems • They can explain the experimental identification of ARX models of dynamic systems, and how the identification problem can be solved by solving a normal equation • They can explain how a state space model can be constructed from a discrete-time impulse response
Skills	• Students can transform transfer function models into state space models and vice versa • They can assess controllability and observability and construct minimal realisations • They can design LQG controllers for multivariable plants • They can carry out a controller design both in continuous-time and discrete-time domain, and decide which is appropriate for a given sampling rate • They can identify transfer function models and state space models of dynamic systems from experimental data • They can carry out all these tasks using standard software tools (Matlab Control Toolbox, System Identification Toolbox, Simulink)
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	Students can obtain information from provided sources (lecture notes, software documentation, experiment guides) and use it when solving given problems. They can assess their knowledge in weekly on-line tests and thereby control their learning progress.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Computational Science and Engineering: Specialisation Kernfächer Ingenieurswissenschaften (2 Kurse): Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory

Course L0656: Control Systems Theory and Design	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	State space methods (single-input single-output) • State space models and transfer functions, state feedback • Coordinate basis, similarity transformations • Solutions of state equations, matrix exponentials, Caley-Hamilton Theorem • Controllability and pole placement • State estimation, observability, Kalman decomposition • Observer-based state feedback control, reference tracking • Transmission zeros • Optimal pole placement, symmetric root locus Multi-input multi-output systems • Transfer function matrices, state space models of multivariable systems, Gilbert realization • Poles and zeros of multivariable systems, minimal realization • Closed-loop stability • Pole placement for multivariable systems, LQR design, Kalman filter Digital Control • Discrete-time systems: difference equations and z-transform • Discrete-time state space models, sampled data systems, poles and zeros • Frequency response of sampled data systems, choice of sampling rate System identification and model order reduction • Least squares estimation, ARX models, persistent excitation • Identification of state space models, subspace identification • Balanced realization and model order reduction Case study • Modelling and multivariable control of a process evaporator using Matlab and Simulink Software tools • Matlab/Simulink
Literature	• Werner, H., Lecture Notes „Control Systems Theory and Design“ • T. Kailath "Linear Systems", Prentice Hall, 1980 • K.J. Astrom, B. Wittenmark "Computer Controlled Systems" Prentice Hall, 1997 • L. Ljung "System Identification - Theory for the User", Prentice Hall, 1999

Course L0657: Control Systems Theory and Design	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1250: Electrical Power Systems II

Courses

Title	Typ	Hrs/wk	CP
Electrical Power Systems II (L1696)	Lecture	2	4
Electrical Power Systems II (L1697)	Recitation Section (large)	2	2

Module Responsible	Prof. Christian Becker
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of Electrical Engineering, Electrical Power Systems I, Mathematics I, II, III
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain in detail and critically evaluate technologies and information systems for operational management of conventional and modern electric power systems as well as methods and algorithms for steady-state network calculation, failure calculation, power system operation and optimization. They are additonally able to apply these methods to real electric power systems.
Skills	With completion of this module the students are able to apply the acquired skills for planning and analysis of real electric power systems and to critically evaluate the results.
Personal Competence	
Social Competence	The students can participate in specialized and interdisciplinary discussions, advance ideas and represent their own work results in front of others.
Autonomy	Students can independently tap knowledge of the emphasis of the lectures and apply it within further research activities.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Electrical Engineering: Core Qualification: Compulsory

Course L1696: Electrical Power Systems II	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Christian Becker
Language	DE
Cycle	WiSe
Content	• steaedy-state modelling of electric power systems ◦ conventional components ◦ Flexible AC Transmission Systems (FACTS) and HVDC ◦ grid modelling • grid operation ◦ electric power supply processes ◦ grid and power system management ◦ grid provision • grid control systems ◦ information and communication systems for power system management ◦ IT architectures of bay-, substation and network control level ◦ IT integration (energy market / supply shortfall management / asset management) ◦ future trends of process control technology ◦ smart grids • functions and steady-state computations for power system operation and plannung ◦ load-flow calculations ◦ sensitivity analysis and power flow control ◦ power system optimization ◦ short-circuit calculation ◦ asymmetric failure calculation ▪ symmetric components ▪ calculation of asymmetric failures ◦ state estimation
Literature	E. Handschin: Elektrische Energieübertragungssysteme, Hüthig Verlag B. R. Oswald: Berechnung von Drehstromnetzen, Springer-Vieweg Verlag V. Crastan: Elektrische Energieversorgung Bd. 1 & 3, Springer Verlag E.-G. Tietze: Netzleittechnik Bd. 1 & 2, VDE-Verlag

Course L1697: Electrical Power Systems II	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christian Becker
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0798: Technical Complementary Course for ETMS (according to Subject Specific Regulations)

Courses			
Title	**Typ**	**Hrs/wk**	**CP**

Module Responsible	Prof. Christian Becker
Admission Requirements	None
Recommended Previous Knowledge	See selected module according to FSPO
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	see selected module according to FSPO
Skills	see selected module according to FSPO
Personal Competence	
Social Competence	see selected module according to FSPO
Autonomy	see selected module according to FSPO
Workload in Hours	Depends on choice of courses
Credit points	12
Assignment for the Following Curricula	Electrical Engineering: Core Qualification: Compulsory

Specialization Microwave Engineering, Optics, and Electromagnetic Compatibility

Module M0548: Bioelectromagnetics: Principles and Applications

Courses

Title	Typ	Hrs/wk	CP
Bioelectromagnetics: Principles and Applications (L0371)	Lecture	3	5
Bioelectromagnetics: Principles and Applications (L0373)	Recitation Section (small)	2	1

Module Responsible	Prof. Christian Schuster
Admission Requirements	None
Recommended Previous Knowledge	Basic principles of physics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the basic principles, relationships, and methods of bioelectromagnetics, i.e. the quantification and application of electromagnetic fields in biological tissue. They can define and exemplify the most important physical phenomena and order them corresponding to wavelength and frequency of the fields. They can give an overview over measurement and numerical techniques for characterization of electromagnetic fields in practical applications . They can give examples for therapeutic and diagnostic utilization of electromagnetic fields in medical technology.
Skills	Students know how to apply various methods to characterize the behavior of electromagnetic fields in biological tissue. In order to do this they can relate to and make use of the elementary solutions of Maxwell's Equations. They are able to assess the most important effects that these models predict for biological tissue, they can order the effects corresponding to wavelength and frequency, respectively, and they can analyze them in a quantitative way. They are able to develop validation strategies for their predictions. They are able to evaluate the effects of electromagnetic fields for therapeutic and diagnostic applications and make an appropriate choice.
Personal Competence	
Social Competence	Students are able to work together on subject related tasks in small groups. They are able to present their results effectively in English (e.g. during small group exercises).
Autonomy	Students are capable to gather information from subject related, professional publications and relate that information to the context of the lecture. They are able to make a connection between their knowledge obtained in this lecture with the content of other lectures (e.g. theory of electromagnetic fields, fundamentals of electrical engineering / physics). They can communicate problems and effects in the field of bioelectromagnetics in English.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** 10 % · **Form** Presentation · **Description**
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0371: Bioelectromagnetics: Principles and Applications	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	- Fundamental properties of electromagnetic fields (phenomena) - Mathematical description of electromagnetic fields (Maxwell’s Equations) - Electromagnetic properties of biological tissue - Principles of energy absorption in biological tissue, dosimetry - Numerical methods for the computation of electromagnetic fields (especially FDTD) - Measurement techniques for characterization of electromagnetic fields - Behavior of electromagnetic fields of low frequency in biological tissue - Behavior of electromagnetic fields of medium frequency in biological tissue - Behavior of electromagnetic fields of high frequency in biological tissue - Behavior of electromagnetic fields of very high frequency in biological tissue - Diagnostic applications of electromagnetic fields in medical technology - Therapeutic applications of electromagnetic fields in medical technology - The human body as a generator of electromagnetic fields
Literature	- C. Furse, D. Christensen, C. Durney, "Basic Introduction to Bioelectromagnetics", CRC (2009) - A. Vorst, A. Rosen, Y. Kotsuka, "RF/Microwave Interaction with Biological Tissues", Wiley (2006) - S. Grimnes, O. Martinsen, "Bioelectricity and Bioimpedance Basics", Academic Press (2008) - F. Barnes, B. Greenebaum, "Bioengineering and Biophysical Aspects of Electromagnetic Fields", CRC (2006)

Course L0373: Bioelectromagnetics: Principles and Applications	
Typ	Recitation Section (small)
Hrs/wk	2
CP	1
Workload in Hours	Independent Study Time 2, Study Time in Lecture 28
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	- Fundamental properties of electromagnetic fields (phenomena) - Mathematical description of electromagnetic fields (Maxwell’s Equations) - Electromagnetic properties of biological tissue - Principles of energy absorption in biological tissue, dosimetry - Numerical methods for the computation of electromagnetic fields (especially FDTD) - Measurement techniques for characterization of electromagnetic fields - Behavior of electromagnetic fields of low frequency in biological tissue - Behavior of electromagnetic fields of medium frequency in biological tissue - Behavior of electromagnetic fields of high frequency in biological tissue - Behavior of electromagnetic fields of very high frequency in biological tissue - Diagnostic applications of electromagnetic fields in medical technology - Therapeutic applications of electromagnetic fields in medical technology - The human body as a generator of electromagnetic fields
Literature	- C. Furse, D. Christensen, C. Durney, "Basic Introduction to Bioelectromagnetics", CRC (2009) - A. Vorst, A. Rosen, Y. Kotsuka, "RF/Microwave Interaction with Biological Tissues", Wiley (2006) - S. Grimnes, O. Martinsen, "Bioelectricity and Bioimpedance Basics", Academic Press (2008) - F. Barnes, B. Greenebaum, "Bioengineering and Biophysical Aspects of Electromagnetic Fields", CRC (2006)

Module M0645: Fibre and Integrated Optics

Courses

Title	Typ	Hrs/wk	CP
Fibre and Integrated Optics (L0363)	Lecture	2	3
Fibre and Integrated Optics (Problem Solving Course) (L0365)	Recitation Section (small)	1	1

Module Responsible	Prof. Manfred Eich
Admission Requirements	None
Recommended Previous Knowledge	Basic principles of electrodynamics and optics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the fundamental mathematical and physical relations and technological basics of guided optical waves. They can describe integrated optical as well as fibre optical structures. They can give an overview on the applications of integrated optical components in optical signal processing.
Skills	Students can generate models and derive mathematical descriptions in relation to fibre optical and integrated optical wave propagation. They can derive approximative solutions and judge factors influential on the components' performance.
Personal Competence	
Social Competence	Students can jointly solve subject related problems in groups. They can present their results effectively within the framework of the problem solving course.
Autonomy	Students are capable to extract relevant information from the provided references and to relate this information to the content of the lecture. They can reflect their acquired level of expertise with the help of lecture accompanying measures such as exam typical exam questions. Students are able to connect their knowledge with that acquired from other lectures.
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Credit points	4
Course achievement	None
Examination	Written exam
Examination duration and scale	40 minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory

Course L0363: Fibre and Integrated Optics

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Hagen Renner
Language	EN
Cycle	SoSe
Content	• Theory of optical waveguides • Coupling to and from waveguides • Losses • Linear and nonlinear dspersion • Components and technical applications
Literature	Bahaa E. A. Saleh, Malvin Carl Teich, Fundamentals of Photonics, Wiley 2007 Hunsperger, R.G., Integrated Optics: Theory and Technology, Springer, 2002 Agrawal, G.P.,Fiber-Optic Communication Systems, Wiley, 2002, ISBN 0471215716 Marcuse, D., Theory of Dielectric Optical Waveguides, Academic Press,1991, ISBN 0124709516 Tamir, T. (ed), Guided-Wave Optoelectronics, Springer, 1990

Course L0365: Fibre and Integrated Optics (Problem Solving Course)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Hagen Renner
Language	EN
Cycle	SoSe
Content	See lecture Fibre and Integrated Optics
Literature	See lecture Fibre and Integrated Optics

Module M0712: Microwave Semiconductor Devices and Circuits I

Courses

Title	Typ	Hrs/wk	CP
Microwave Semiconductor Devices and Circuits I (L0580)	Lecture	3	4
Microwave Semiconductor Devices and Circuits I (L0581)	Recitation Section (large)	2	2

Module Responsible	Prof. Arne Jacob
Admission Requirements	None
Recommended Previous Knowledge	Electrical Engineering IV, Microwave Engineering, Fundamentals of Semiconductor Technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are capable of explaining the functionality of amplifier, mixer, and oscillator in detail. They can present theories, concepts, and reasonable assumptions for description and synthesis of these devices. They are able to apply thorough knowledge of semiconductor physics of selected microwave devices to amplifier, mixer, and oscillator. They can compare different devices with respect to various parameters (such as frequency range, power und efficiency).
Skills	The students can assess occurring linear and nonlinear effects in active microwave circuits and are capable of analyzing and evaluating them. They are able to develop passive and active linear microwave circuits with the help of modern software-tools, taking application requirements into account.
Personal Competence	
Social Competence	The students are able to carry out subject-specific tasks in small groups, and to adequately present solutions (e.g. in CAD-Exercises).
Autonomy	The students are able to obtain additional information from given literature sources and set the content in context with the lecture. They can link and deepen their knowledge of other courses, e.g., Electrical Engineering IV, Theoretical Engineering, Microwave Engineering, Semiconductor Devices. The students acquire the ability to communicate problems and solutions in the field of microwave semiconductor devices and circuits in English.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory

Course L0580: Microwave Semiconductor Devices and Circuits I	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	SoSe
Content	- Amplifier: S-Parameters, stability, gain definitions; Bipolar Junction Transistor and HBT, MESFET and HEMT; Circuit applications, nonlinear distortions, low noise and power amplifier - Mixer: Conversion matrix analysis; pn- and Schottky-diode, FET; Circuit applications, conversion gain and noise figure - Oszillator: Oscillation start-up, steady state operation, stability; IMPATT-diode, Gunn-element, FET; oscillator stabilization - Linear passive circuits: Planar microwave circuits, quarterwave matching circuits and discontinuities, lowpass-filter and bandpass-filter synthesis - Design of active circuits
Literature	- E. Voges, „Hochfrequenztechnik“, Hüthig (2004) - H.-G. Unger, W. Harth, „Hochfrequenz-Halbleiterelektronik“, S. Hirzel Verlag (1972) - S.M. Sze, „Physics of Semiconductor Devices”, John Wiley & Sons (1981) - A. Jacob, „Lecture Notes Microwave Semiconductor Devices and Circuits Part I“

Course L0581: Microwave Semiconductor Devices and Circuits I	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1016: Optical Communications

Courses

Title	Typ	Hrs/wk	CP
Optical Communication (L0477)	Lecture	2	3
Optical Communication (L0480)	Recitation Section (large)	1	1

Module Responsible	Dr. Hagen Renner
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of Electrical Engineering, Communication Engineering, Electronics Components
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The aim of this course is imparting profound knowledge and analytical skills in the following fields: - Fundamentals of Optical Waveguiding - Properties of Optical Silica Fibers - Passive Components for Optical Communications - Fundamentals of Photodiodes and LEDs - Noise in Photodetectors - Laser Diodes - Optical Amplifiers - Nonlinearities in Optical Fibers - Optical Communication Systems
Skills	Fundamental skills are imparted with respect to the modelling of basic optical communication systems and fundamental optical components as well as to estimating the influence of important causes of impairement.
Personal Competence	
Social Competence	
Autonomy	In the excersises the autonomous aplication of the knowledge gained in the lecture to specific problems of Optical Communications will be trained.
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Credit points	4
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory

Course L0477: Optical Communication

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	SoSe
Content	**Optical Communications** • Optical waveguide fundamentals ∘ total internal reflection at plane dielectric interfaces ∘ slab waveguides ∘ rays in step-index and graded-index “multi-mode” fibers ∘ modes in optical fibers ∘ single-mode fibers ∘ fabrication of fibers • Properties of silica optical fiber relevant in communications ∘ attenuation by scattering and absorption ∘ dispersion and pulse broadening ∘ polarization mode dispersion • Passive fiber optical components ∘ excitation of fibers, splice/connector loss ∘ fiber optical directional couplers ∘ isolators, circulators, phased arrays, grating components

	- Photodiode and LED fundamentals - pin-photodiodes: responsivity, response time, equivalent circuit - avalanche photodiodes - light emitting diodes: spectra, output power, modulation - Noise in photodetectors - power spectral density of a train of randomly occuring events - shot noise and thermal noise - photodetector equivalent circuits with noise sources - basic receiver considerations - Laserdiodes - basic laser physics - Fabry-Perot laser diodes - rate equations and LD characteristics - special laser diodes - Optical fiber amplifiers - Erbium in silica fibers: energy levels, transitions, cross sections, amplification - noise in optical amplifiers: spontaneous emission, ASE, noise figure, periodic amplification - modelling of optical amplifiers - examples and applications - Nonlinearities in optical fibers - basic nonlinear effects - solitons for high bit rate transmission: dispersion vs. self phase modulation - Optical fiber systems
Literature	[1] G.P. Agrawal, "Fiber-optic communication systems", Wiley-Interscience, 2002 [2] J. Gowar: "Opical Communication Systems", Prentice Hall 199 [3] I.P. Kaminov and L. Koch (ed.): "Optical Fiber Telecomminications", volume IIIA and IIIB, Academic Press, 1997 [4] A. Yariv: "Optical Electronics", Sauders College Publishing, 1997 [5] E.G. Neumann: "Single-Mode Fibers", Springer 1988 [6] H.G. Unger: "Optische Nachrichtentechnik", volume I and II, Hüthig 1992 (in German) [7] J.M. Senior: "Optical Fiber communications", Prentice Hall 2009 [8] E. Voges and K. Petermann (ed.): "Optische Kommunikationstechnik", Springer 2002 (in German)

Course L0480: Optical Communication	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0769: EMC I: Coupling Mechanisms, Countermeasures and Test Procedures

Courses

Title	Typ	Hrs/wk	CP
EMC I: Coupling Mechanisms, Countermeasures, and Test Procedures (L0743)	Lecture	3	4
EMC I: Coupling Mechanisms, Countermeasures, and Test Procedures (L0744)	Recitation Section (small)	1	1
EMC I: Coupling Mechanisms, Countermeasures, and Test Procedures (L0745)	Practical Course	1	1

Module Responsible	Prof. Christian Schuster
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of Electrical Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain the fundamental principles, inter-dependencies, and methods of Electromagnetic Compatibility of electric and electronic systems and to ensure Electromagnetic Compatibility of such systems. They are able to classify and explain the common interference sources and coupling mechanisms. They are capable of explaining the basic principles of shielding and filtering. They are able of giving an overview over measurement and simulation methods for the characterization of Electromagnetic Compatibility in electrical engineering practice.
Skills	Students are able to apply a series of modeling methods for the Electromagnetic Compatibility of typical electric and electronic systems. They are able to determine the most important effects that these models are predicting in terms of Electromagnetic Compatibility. They can classify these effects and they can quantitatively analyze them. They are capable of deriving problem solving strategies from these predictions and they can adapt them to applications in electrical engineering practice. They can evaluate their problem solving strategies against each other.
Personal Competence	
Social Competence	Students are able to work together on subject related tasks in small groups. They are able to present their results effectively in English, during laboratory work and exercises, e.g..
Autonomy	Students are capable to gather necessary information from the references provided and relate that information to the context of the lecture. They are able to make a connection between their knowledge obtained in this lecture with the content of other lectures (e.g. Theoretical Electrical Engineering and Communication Theory). They can communicate problems and solutions in the field of Electromagnetic Compatibility in english language.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Presentation; **Description**
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory

Course L0743: EMC I: Coupling Mechanisms, Countermeasures, and Test Procedures

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	• Introduction to Electromagnetic Compatibility (EMC) • Interference sources in time an frequency domain • Coupling mechanisms • Transmission lines and coupling to electromagnetic fields • Shielding • Filters • EMC test procedures
Literature	• C.R. Paul: "Introduction to Electromagnetic Compatibility", 2nd ed., (Wiley, New Jersey, 2006). • A.J. Schwab und W. Kürner: "Elektromagnetische Verträglichkeit", 6. Auflage, (Springer, Berlin 2010). • F.M. Tesche, M.V. Ianoz, and T. Karlsson: "EMC Analysis Methods and Computational Models", (Wiley, New York, 1997).

Course L0744: EMC I: Coupling Mechanisms, Countermeasures, and Test Procedures	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	The exercise sessions serve to deepen the understanding of the concepts of the lecture.
Literature	• C.R. Paul: "Introduction to Electromagnetic Compatibility", 2nd ed., (Wiley, New Jersey, 2006). • A.J. Schwab und W. Kürner: "Elektromagnetische Verträglichkeit", 6. Auflage, (Springer, Berlin 2010). • F.M. Tesche, M.V. Ianoz, and T. Karlsson: "EMC Analysis Methods and Computational Models", (Wiley, New York, 1997). • Scientific articles and papers

Course L0745: EMC I: Coupling Mechanisms, Countermeasures, and Test Procedures	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	Laboratory experiments serve to practically investigate the following EMC topics: • Shielding • Conducted EMC test procedures • The GTEM-cell as an environment for radiated EMC test
Literature	Versuchsbeschreibungen und zugehörige Literatur werden innerhalb der Veranstaltung bereit gestellt.

Module M0643: Optoelectronics I - Wave Optics

Courses

Title	Typ	Hrs/wk	CP
Optoelectronics I: Wave Optics (L0359)	Lecture	2	3
Optoelectronics I: Wave Optics (Problem Solving Course) (L0361)	Recitation Section (small)	1	1

Module Responsible	Prof. Manfred Eich
Admission Requirements	None
Recommended Previous Knowledge	Basics in electrodynamics, calculus
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the fundamental mathematical and physical relations of freely propagating optical waves. They can give an overview on wave optical phenomena such as diffraction, reflection and refraction, etc. Students can describe waveoptics based components such as electrooptical modulators in an application oriented way.
Skills	Students can generate models and derive mathematical descriptions in relation to free optical wave propagation. They can derive approximative solutions and judge factors influential on the components' performance.
Personal Competence	
Social Competence	Students can jointly solve subject related problems in groups. They can present their results effectively within the framework of the problem solving course.
Autonomy	Students are capable to extract relevant information from the provided references and to relate this information to the content of the lecture. They can reflect their acquired level of expertise with the help of lecture accompanying measures such as exam typical exam questions. Students are able to connect their knowledge with that acquired from other lectures.
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Credit points	4
Course achievement	None
Examination	Written exam
Examination duration and scale	40 minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory

Course L0359: Optoelectronics I: Wave Optics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	SoSe
Content	• Introduction to optics • Electromagnetic theory of light • Interference • Coherence • Diffraction • Fourier optics • Polarisation and Crystal optics • Matrix formalism • Reflection and transmission • Complex refractive index • Dispersion • Modulation and switching of light
Literature	Bahaa E. A. Saleh, Malvin Carl Teich, Fundamentals of Photonics, Wiley 2007 Hecht, E., Optics, Benjamin Cummings, 2001 Goodman, J.W. Statistical Optics, Wiley, 2000 Lauterborn, W., Kurz, T., Coherent Optics: Fundamentals and Applications, Springer, 2002

Course L0361: Optoelectronics I: Wave Optics (Problem Solving Course)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	SoSe
Content	see lecture Optoelectronics 1 - Wave Optics
Literature	see lecture Optoelectronics 1 - Wave Optics

Module M0784: Introduction to Antenna Theory

Courses

Title	Typ	Hrs/wk	CP
Introduction To Antenna Theory (L0783)	Lecture	2	3
Introduction To Antenna Theory (L0784)	Recitation Section (large)	1	1
Introduction To Antenna Theory (L1349)	Practical Course	1	2

Module Responsible	Prof. Arne Jacob
Admission Requirements	None
Recommended Previous Knowledge	Electrical Engineering IV, Theoretical Electrical Engineering II, Microwave Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to apply the fundamental theory and approximations regarding the propagation of electromagnetic waves on transmission lines and in free space specifically with regard to antenna design problems. They are able to evaluate which method of analysis is suitable for certain antennas. They are able to derive the field solutions for different antenna types. The students are able to illustrate the functionality and radiation behavior of antennas based on physical principles. Additionally, the functionality of arrangements of several antennas (arrays) can be evaluated by the students.
Skills	The students are capable of applying different methods which are used for antenna characterization in a problem related manner. By means of the analysis of different antenna types the students are able to assess which antenna is adequate for a certain situation, e.g., with respect to the radiation pattern or the input resistance. They have the knowledge to handle advanced antenna and radiation problems in an autonomous way. In lecture-accompanying CAD exercises and laboratory experiments the students are capable of verifying the related approximations and assessing their accuracy and validity. This way, they are able to compare the theory with numerical and experimental methods.
Personal Competence	
Social Competence	The students are able to work in small groups in the CAD exercises and the laboratory experiments to discuss tasks related to the subject. They are able to present and demonstrate their knowledge in a suitable manner.
Autonomy	The students are able to obtain supplementary information from the indicated literature sources and to relate it to the content of the lecture. They are capable of deepening and linking their achieved knowledge with the contents of other lectures (e.g. Microwave Engineering, Theoretical Electrical Engineering II). The students acquire the ability to choose and develop the right antenna type for a certain situation under given conditions in a self-contained way.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description**: Yes / None / Subject theoretical and practical work /
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory

Course L0783: Introduction To Antenna Theory	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	SoSe
Content	- Basic principles: Near and far field, approximate solutions, Poynting Theorem - Wire antennas: loop antenna, folded dipole, discone and conical-skirt monopole, traveling-wave antenna, long-wire antenna, helical antenna - Horn antennas: rectangular aperture, circular aperture, corrugated horn - Reflector antennas: Geometrical Optics, Geometrical Theory of Diffraction - Antenna arrays: array factor, beam scanning, uniformly and non-uniformly excited linear arrays, array feeds - CAD tools for electrical analysis and design of antennas and arrays - Experimental antenna characterization
Literature	- H.-G. Unger, "Hochfrequenztechnik in Funk und Radar" Teubner (1994) - C. A. Balanis, "Antenna Theory - Analysis and Design 3rd ed." Wiley-Interscience (2005) - C. A. Balanis, "Advanced Engineering Electromagnetics" Wiley (1989)

Course L0784: Introduction To Antenna Theory	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1349: Introduction To Antenna Theory	
Typ	Practical Course
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0785: Electromagnetic Waves

Courses

Title	Typ	Hrs/wk	CP
Electromagnetic Waves (L0785)	Lecture	2	3
Electromagnetic Waves (L0786)	Recitation Section (large)	1	1
Electromagnetic Waves (L1346)	Practical Course	1	2

Module Responsible	Prof. Arne Jacob
Admission Requirements	None
Recommended Previous Knowledge	Electrical Engineering IV, Theoretical Electrical Engineering II, Microwave Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Based on Maxwell's Equations the students are capable of computing field quantities of electromagnetic waves by means of scalar potentials. From these fields the students can then identify propagation characteristics and attenuation of electromagnetic waves on various structures. Furthermore, the students understand the effects of discontinuities on the propagation of modes and how these effects can be modelled by lumped equivalent circuits. The description of general microwave networks, as well as arbitrarily shaped cylindrical waveguides allow the students to account for and analyze a multitude of microwave problems. By means of perturbation and variational approaches the students are able to formulate problems such that the application to optimization processes or other numerical methods is possible. An easy final example gives the students a first glance at the method of moments that allows the solution of subject-specific problems on computers. In the laboratory experiments the theories presented in the lecture and the exercises are directly applied and quantified by small groups of students using measurements.
Skills	The students are capable of analyzing simple electromagnetic problems, as well as making qualitative statements about the effects on wave propagation. Basic effects of discontinuities, e.g. waveguide transitions, can be predicted and assessed. By means of the outlined methods the students are able to evaluate non-standard problems both qualitatively and quantitatively. Due to the generality of the covered approaches the students can link these methods with various classes of problems in order to develop intuitive solutions. In accompanying laboratory experiments the students have the opportunity to apply and verify the learned methods practically.
Personal Competence	
Social Competence	The students work together in small groups in the course of the laboratory experiments on subject-specific tasks. The results are presented and documented in a professional manner.
Autonomy	The students are able to obtain additional information from given literature sources and set the content in context with the lecture. They can link and deepen their knowledge of other courses, e.g. Microwave Engineering and Theoretical Electrical Engineering II. The students obtain the ability to predict the behavior of electromagnetic components and to develop solutions in order to achieve a desired functionality. Both of these tasks can be done by the students in a self-contained way.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description**: Yes / None / Subject theoretical and practical work /
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory

Course L0785: Electromagnetic Waves	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	SoSe
Content	- General properties of fields and plane waves: General solution of Maxwell’s Equations (in Cartesian coordinates), plane waves, rectangular waveguide, attenuation in waveguides, degenerate modes, cavity resonators, partially dielectrically filled rectangular wavguide, dielectric slab waveguide, surface waveguides, leaky waves. - Field expansions: Modal expansions of rectangular waveguide and at waveguide transitions, field expansions in free space. - Microwave circuits: cylindrical waveguides, N-port networks. - Perturbation and variational approaches: Stationary formulas, Rayleigh-Ritz procedure, reaction concept. - Method of moments: Formulation of problems, point matching, subsectional bases, approximate operators, Green’s functions, Application to scattering problems, wavelets as basis functions.
Literature	- H.-G. Unger, "Elektromagnetische Theorie für die Hochfrequenztechnik", Teil I+II, Teubner (1988) - R. F. Harrington, "Time-Harmonic Electromagnetic Fields", Wiley-Interscience (1961 - R. F. Harrington, "Field Computation by Moment Methods", Robert E. Krieger Publ. Comp. (1968)

Course L0786: Electromagnetic Waves	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1346: Electromagnetic Waves	
Typ	Practical Course
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0795: Research Project in Microwave Engineering, Optics and Electromagnetic Compatibility

Courses

Title	Typ	Hrs/wk	CP

Module Responsible	Dozenten des SD E
Admission Requirements	None
Recommended Previous Knowledge	Advanced state of knowledge in the electrical engineering master program
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know current research topics oft institutes engaged in their specialization. They can name the fundamental scientific methods used for doing related reserach.
Skills	Strudents are capable of completing a small, independent sub-project of currently ongoing research projects in the institutes engaged in their specialization. Students can justify and explain their approach for problem solving, they can draw conclusions from their results, and then can find new ways and methods for their work. Students are capable of comparing and assessing alterantive approaches with their own with regard to given criteria.
Personal Competence	
Social Competence	Students are able to discuss their work progress with research assistants of the supervising institute . They are capable of presenting their results in front of a professional audience.
Autonomy	Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research project for themselves. They are able to develop the necessary understanding and problem solving methods.
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Study work
Examination duration and scale	acc. to ASPO
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Compulsory

Module M0781: EMC II: Signal Integrity and Power Supply of Electronic Systems

Courses

Title	Typ	Hrs/wk	CP
EMC II: Signal Integrity and Power Supply of Electronic Systems (L0770)	Lecture	3	4
EMC II: Signal Integrity and Power Supply of Electronic Systems (L0771)	Recitation Section (small)	1	1
EMC II: Signal Integrity and Power Supply of Electronic Systems (L0774)	Practical Course	1	1

Module Responsible	Prof. Christian Schuster
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of electrical engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain the fundamental principles, inter-dependencies, and methods of signal and power integrity of electronic systems. They are able to relate signal and power integrity to the context of interference-free design of such systems, i.e. their electromagnetic compatibility. They are capable of explaining the basic behavior of signals and power supply in typical packages and interconnects. They are able to propose and describe problem solving strategies for signal and power integrity issues. They are capable of giving an overview over measurement and simulation methods for characterization of signal and power integrity in electrical engineering practice.
Skills	Students are able to apply a series of modeling methods for characterization of electromagnetic field behavior in packages and interconnect structure of electronic systems. They are able to determine the most important effects that these models are predicting in terms of signal and power integrity. They can classify these effects and they can quantitatively analyze them. They are capable of deriving problem solving strategies from these predictions and they can adapt them to applications in electrical engineering practice. The can evaluate their problem solving strategies against each other.
Personal Competence	
Social Competence	Students are able to work together on subject related tasks in small groups. They are able to present their results effectively in English (e.g. during CAD exercises).
Autonomy	Students are capable to gather necessary information from the references provided and relate that information to the context of the lecture. They are able to make a connection between their knowledge obtained in this lecture with the content of other lectures (e.g. theory of electromagnetic fields, communications, and semiconductor circuit design). They can communicate problems and solutions in the field of signal integrity and power supply of interconnect and packages in English.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Presentation; **Description**
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory

Course L0770: EMC II: Signal Integrity and Power Supply of Electronic Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	- The role of packages and interconnects in electronic systems - Components of packages and interconnects in electronic systems - Main goals and concepts of signal and power integrity of electronic systems - Repeat of relevant concepts from the theory electromagnetic fields - Properties of digital signals and systems - Design and characterization of signal integrity - Design and characterization of power supply - Techniques and devices for measurements in time- and frequency-domain - CAD tools for electrical analysis and design of packages and interconnects - Connection to overall electromagnetic compatibility of electronic systems
Literature	- J. Franz, "EMV: Störungssicherer Aufbau elektronischer Schaltungen", Springer (2012) - R. Tummala, "Fundamentals of Microsystems Packaging", McGraw-Hill (2001) - S. Ramo, J. Whinnery, T. Van Duzer, "Fields and Waves in Communication Electronics", Wiley (1994) - S. Thierauf, "Understanding Signal Integrity", Artech House (2010) - M. Swaminathan, A. Engin, "Power Integrity Modeling and Design for Semiconductors and Systems", Prentice-Hall (2007)

Course L0771: EMC II: Signal Integrity and Power Supply of Electronic Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0774: EMC II: Signal Integrity and Power Supply of Electronic Systems	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	- The role of packages and interconnects in electronic systems - Components of packages and interconnects in electronic systems - Main goals and concepts of signal and power integrity of electronic systems - Repeat of relevant concepts from the theory electromagnetic fields - Properties of digital signals and systems - Design and characterization of signal integrity - Design and characterization of power supply - Techniques and devices for measurements in time- and frequency-domain - CAD tools for electrical analysis and design of packages and interconnects - Connection to overall electromagnetic compatibility of electronic systems
Literature	- J. Franz, "EMV: Störungssicherer Aufbau elektronischer Schaltungen", Springer (2012) - R. Tummala, "Fundamentals of Microsystems Packaging", McGraw-Hill (2001) - S. Ramo, J. Whinnery, T. Van Duzer, "Fields and Waves in Communication Electronics", Wiley (1994) - S. Thierauf, "Understanding Signal Integrity", Artech House (2010) - M. Swaminathan, A. Engin, "Power Integrity Modeling and Design for Semiconductors and Systems", Prentice-Hall (2007)

Module M1243: Seminar on Microwave Engineering

Courses

Title	Typ	Hrs/wk	CP
Seminar on Microwave Engineering (L1689)	Seminar	2	2

Module Responsible	Prof. Arne Jacob
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of communication engineering, semiconductor devices and circuits. Basics of Wave propagation from transmission line theory and theoretical electrical engineering.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the most important facts and relationships of a specific topic from the field of high-frequency technology.
Skills	Students are able to compile a specified topic from the field of high-frequency technology and to give a clear, structured and comprehensible presentation of the subject.
Personal Competence	
Social Competence	Students are able to adapt their presentation with respect to content, detailedness, and presentation style to the composition and previous knowledge of the audience. They can answer questions from the audience in a curt and precise manner.
Autonomy	Students are able to autonomously carry out a literature research concerning a given topic. They can independently evaluate the material. They can self-reliantly decide which parts of the material should be included in the presentation.
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory

Course L1689: Seminar on Microwave Engineering

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Arne Jacob
Language	EN
Cycle	WiSe/SoSe
Content	Seminar talk on a given subject
Literature	Themenabhängig / subject related

Module M0788: Microwave Semiconductor Devices and Circuits II

Courses

Title	Typ	Hrs/wk	CP
Microwave Semiconductor Devices and Circuits II (L0788)	Lecture	1	1
Microwave Semiconductor Devices and Circuits II (L0789)	Recitation Section (large)	1	1
Microwave Circuit Design Laboratory (L0790)	Practical Course	4	4

Module Responsible	Prof. Arne Jacob
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of Semiconductor Technology, Microwave Engineering, Microwave Semiconductor Devices and Circuits I
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are capable of explaining the functionality of frequency multipliers in detail. They can present theories, concepts, and reasonable assumptions for description and synthesis. They are able to apply indepth knowledge on semiconductor physics of selected microwave devices to the frequency multiplier. Students can describe microwave measurement methods.
Skills	The students can assess effects occurring in active microwave circuits and are capable of analyzing and evaluating them. They are able to design and realize linear and nonlinear microwave circuits with help of modern software tools, taking application and manufacturing requirements into account. They are able to select and apply suitable measurement techniques.
Personal Competence	
Social Competence	The students are able to carry out subject-specific tasks in small groups, and to adequately present solutions (e.g. in microwave circuit design laboratory). They are capable of assessing and reflecting their contribution to the overall project (satellite receiver). They are able to communicate with different groups and with a supervisor, and to handle feedback on their own performance constructively.
Autonomy	The students are able to obtain additional information from given literature sources and set the content in context with the lecture. They can link and deepen their knowledge of other courses and translate their knowledge to practical situation. The students acquire the ability to communicate problems and solutions in the field of microwave semiconductor devices and circuits in English. They can assess their abilities and results of their work and evaluate the necessity of support.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Subject theoretical and practical work; **Description**
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory

Course L0788: Microwave Semiconductor Devices and Circuits II	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	WiSe
Content	- Frequency multiplier: Harmonic balance, noise in nonlinear circuits; Step Recovery Diode, FET; circuit synthesis, large signal, noise, and stability analysis - Low Noise Amplifier (LNA) circuit design: Stability and stability circles, gain and gain circles, noise, noise figure and noise figure circles - Mixer, oscillator: Measurement techniques (Network analyzer, Spectrum analyzer, Frequency generator)
Literature	- E. Voges, „Hochfrequenztechnik“, Hüthig (2004) - H.-G. Unger, W. Harth, „Hochfrequenz-Halbleiterelektronik“, S. Hirzel Verlag (1972) - S.M. Sze, "Physics of Semiconductor Devices", John Wiley & Sons (1981) - A. Jacob, "Lecture Notes Microwave Semiconductor Devices and Circuits Part II"

Course L0789: Microwave Semiconductor Devices and Circuits II	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0790: Microwave Circuit Design Laboratory	
Typ	Practical Course
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Arne Jacob
Language	DE/EN
Cycle	WiSe
Content	- Satellite receiver at X-Band (low noise amplifier, mixer, oscillator): Circuit and system design, realization, and characterization
Literature	- A. Jacob, "Microwave Circuit Design Laboratory Guide"

Module M0666: Seminar on Electromagnetic Compatibility and Electrical Power Systems

Courses

Title	Typ	Hrs/wk	CP
Seminar on Electromagnetic Compatibility and Electrical Power Systems (L0409)	Seminar	2	2

Module Responsible	Prof. Christian Schuster
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of electrical engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know current research topics in the fields of electromagnetic compatibility, theory of electromagnetic fields, and electrical power systems. They are able to use professional language in discussions. They are able to explain research topics.
Skills	Students are able to gain knowledge about a new field by themselves. In order to do that they make use of their existing knowledge and try to connect it with the topics of the new field. They close their knowledge gaps by discussing with research assistants and by their own literature and internet search. They are capable of summarizing and presenting scientific publications.
Personal Competence	
Social Competence	In cooperation with research assistants students are able to familiarize themselves with and discuss with others current research topics. They are capable of drafting, presenting, and explaining summaries of these topics in English in front of a professional audience.
Autonomy	Students are capable of gathering information from subject related, professional publications and relate that information to the context of the seminar. They are able to find on their own new sources in the Internet. They are able to make a connection with the subject of their chosen specialization.
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	20-30 minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory

Course L0409: Seminar on Electromagnetic Compatibility and Electrical Power Systems	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christian Schuster, Prof. Frank Gronwald, Prof. Christian Becker
Language	EN
Cycle	WiSe/SoSe
Content	Current research topics in the fields electromagnetic compatibility, theory of electromagnetic fields, and electrical power systems
Literature	Aktuelle Literatur zu Forschungsthemen aus der elektromagnetischen Verträglichkeit, der theoretischen Elektrotechnik und der elektrischen Energiesystemtechnik / Current literature with regard to research topics in the fields of electromagnetic compatibility, theory of electromagnetic fields, and and electrical power systems

Module M0644: Optoelectronics II - Quantum Optics

Courses

Title	Typ	Hrs/wk	CP
Optoelectronics II: Quantum Optics (L0360)	Lecture	2	3
Optoelectronics II: Quantum Optics (Problem Solving Course) (L0362)	Recitation Section (small)	1	1

Module Responsible	Prof. Manfred Eich
Admission Requirements	None
Recommended Previous Knowledge	Basic principles of electrodynamics, optics and quantum mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the fundamental mathematical and physical relations of quantum optical phenomena such as absorption, stimulated and spontanous emission. They can describe material properties as well as technical solutions. They can give an overview on quantum optical components in technical applications.
Skills	Students can generate models and derive mathematical descriptions in relation to quantum optical phenomena and processes. They can derive approximative solutions and judge factors influential on the components' performance.
Personal Competence	
Social Competence	Students can jointly solve subject related problems in groups. They can present their results effectively within the framework of the problem solving course.
Autonomy	Students are capable to extract relevant information from the provided references and to relate this information to the content of the lecture. They can reflect their acquired level of expertise with the help of lecture accompanying measures such as exam typical exam questions. Students are able to connect their knowledge with that acquired from other lectures.
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Credit points	4
Course achievement	None
Examination	Written exam
Examination duration and scale	40 minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory

Course L0360: Optoelectronics II: Quantum Optics

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	WiSe
Content	• Generation of light • Photons • Thermal and nonthermal light • Laser amplifier • Noise • Optical resonators • Spectral properties of laser light • CW-lasers (gas, solid state, semiconductor) • Pulsed lasers
Literature	Bahaa E. A. Saleh, Malvin Carl Teich, Fundamentals of Photonics, Wiley 2007 Demtröder, W., Laser Spectroscopy: Basic Concepts and Instrumentation, Springer, 2002 Kasap, S.O., Optoelectronics and Photonics: Principles and Practices, Prentice Hall, 2001 Yariv, A., Quantum Electronics, Wiley, 1988 Wilson, J., Hawkes, J., Optoelectronics: An Introduction, Prentice Hall, 1997, ISBN: 013103961X Siegman, A.E., Lasers, University Science Books, 1986

Course L0362: Optoelectronics II: Quantum Optics (Problem Solving Course)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	WiSe
Content	see lecture Optoelectronics 1 - Wave Optics
Literature	see lecture Optoelectronics 1 - Wave Optics

Specialization Medical Technology

The specialization ‚Medical Technology‘ offers students the opportunity to put an interdisciplinary focus in their studies. On the one hand, a series of technical modules foster an in-depth understanding of modern medical technology, particularly with respect to electrical engineering. On the other hand, modules on medical topics provide insight into clinical problems, environments and terminology. Students will be able to design, implement, and evaluate methods, algorithms and systems in the context of clinical scenarios. The assessment will be based on their knowledge of the complex system ‘patient’. Hence, competencies developed in this specialization at the interface between electrical engineering and medicine prepare students for positions in industry and academia.

Module M0548: Bioelectromagnetics: Principles and Applications

Courses

Title	Typ	Hrs/wk	CP
Bioelectromagnetics: Principles and Applications (L0371)	Lecture	3	5
Bioelectromagnetics: Principles and Applications (L0373)	Recitation Section (small)	2	1

Module Responsible	Prof. Christian Schuster
Admission Requirements	None
Recommended Previous Knowledge	Basic principles of physics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the basic principles, relationships, and methods of bioelectromagnetics, i.e. the quantification and application of electromagnetic fields in biological tissue. They can define and exemplify the most important physical phenomena and order them corresponding to wavelength and frequency of the fields. They can give an overview over measurement and numerical techniques for characterization of electromagnetic fields in practical applications . They can give examples for therapeutic and diagnostic utilization of electromagnetic fields in medical technology.
Skills	Students know how to apply various methods to characterize the behavior of electromagnetic fields in biological tissue. In order to do this they can relate to and make use of the elementary solutions of Maxwell’s Equations. They are able to assess the most important effects that these models predict for biological tissue, they can order the effects corresponding to wavelength and frequency, respectively, and they can analyze them in a quantitative way. They are able to develop validation strategies for their predictions. They are able to evaluate the effects of electromagnetic fields for therapeutic and diagnostic applications and make an appropriate choice.
Personal Competence	
Social Competence	Students are able to work together on subject related tasks in small groups. They are able to present their results effectively in English (e.g. during small group exercises).
Autonomy	Students are capable to gather information from subject related, professional publications and relate that information to the context of the lecture. They are able to make a connection between their knowledge obtained in this lecture with the content of other lectures (e.g. theory of electromagnetic fields, fundamentals of electrical engineering / physics). They can communicate problems and effects in the field of bioelectromagnetics in English.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 10 %; **Form** Presentation; **Description**
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0371: Bioelectromagnetics: Principles and Applications	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	- Fundamental properties of electromagnetic fields (phenomena) - Mathematical description of electromagnetic fields (Maxwell's Equations) - Electromagnetic properties of biological tissue - Principles of energy absorption in biological tissue, dosimetry - Numerical methods for the computation of electromagnetic fields (especially FDTD) - Measurement techniques for characterization of electromagnetic fields - Behavior of electromagnetic fields of low frequency in biological tissue - Behavior of electromagnetic fields of medium frequency in biological tissue - Behavior of electromagnetic fields of high frequency in biological tissue - Behavior of electromagnetic fields of very high frequency in biological tissue - Diagnostic applications of electromagnetic fields in medical technology - Therapeutic applications of electromagnetic fields in medical technology - The human body as a generator of electromagnetic fields
Literature	- C. Furse, D. Christensen, C. Durney, "Basic Introduction to Bioelectromagnetics", CRC (2009) - A. Vorst, A. Rosen, Y. Kotsuka, "RF/Microwave Interaction with Biological Tissues", Wiley (2006) - S. Grimnes, O. Martinsen, "Bioelectricity and Bioimpedance Basics", Academic Press (2008) - F. Barnes, B. Greenebaum, "Bioengineering and Biophysical Aspects of Electromagnetic Fields", CRC (2006)

Course L0373: Bioelectromagnetics: Principles and Applications	
Typ	Recitation Section (small)
Hrs/wk	2
CP	1
Workload in Hours	Independent Study Time 2, Study Time in Lecture 28
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	- Fundamental properties of electromagnetic fields (phenomena) - Mathematical description of electromagnetic fields (Maxwell’s Equations) - Electromagnetic properties of biological tissue - Principles of energy absorption in biological tissue, dosimetry - Numerical methods for the computation of electromagnetic fields (especially FDTD) - Measurement techniques for characterization of electromagnetic fields - Behavior of electromagnetic fields of low frequency in biological tissue - Behavior of electromagnetic fields of medium frequency in biological tissue - Behavior of electromagnetic fields of high frequency in biological tissue - Behavior of electromagnetic fields of very high frequency in biological tissue - Diagnostic applications of electromagnetic fields in medical technology - Therapeutic applications of electromagnetic fields in medical technology - The human body as a generator of electromagnetic fields
Literature	- C. Furse, D. Christensen, C. Durney, "Basic Introduction to Bioelectromagnetics", CRC (2009) - A. Vorst, A. Rosen, Y. Kotsuka, "RF/Microwave Interaction with Biological Tissues", Wiley (2006) - S. Grimnes, O. Martinsen, "Bioelectricity and Bioimpedance Basics", Academic Press (2008) - F. Barnes, B. Greenebaum, "Bioengineering and Biophysical Aspects of Electromagnetic Fields", CRC (2006)

Module M0630: Robotics and Navigation in Medicine

Courses

Title	Typ	Hrs/wk	CP
Robotics and Navigation in Medicine (L0335)	Lecture	2	3
Robotics and Navigation in Medicine (L0338)	Project Seminar	2	2
Robotics and Navigation in Medicine (L0336)	Recitation Section (small)	1	1

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	• principles of math (algebra, analysis/calculus) • principles of programming, e.g., in Java or C++ • solid R or Matlab skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can explain kinematics and tracking systems in clinical contexts and illustrate systems and their components in detail. Systems can be evaluated with respect to collision detection and safety and regulations. Students can assess typical systems regarding design and limitations.
Skills	The students are able to design and evaluate navigation systems and robotic systems for medical applications.
Personal Competence	
Social Competence	The students discuss the results of other groups, provide helpful feedback and can incoorporate feedback into their work.
Autonomy	The students can reflect their knowledge and document the results of their work. They can present the results in an appropriate manner.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 10 % / Written elaboration Yes / 10 % / Presentation
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0335: Robotics and Navigation in Medicine	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	- kinematics - calibration - tracking systems - navigation and image guidance - motion compensation The seminar extends and complements the contents of the lecture with respect to recent research results.
Literature	Spong et al.: Robot Modeling and Control, 2005 Troccaz: Medical Robotics, 2012 Further literature will be given in the lecture.

Course L0338: Robotics and Navigation in Medicine	
Typ	Project Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0336: Robotics and Navigation in Medicine	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0635: Medical Technology Lab

Courses

Title	Typ	Hrs/wk	CP
Medical Technology Lab (L1096)	Project-/problem-based Learning	6	6

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	sound programming skills (Java / C++) skills in R/Matlab knowledge of image processing principles of math (algebra, analysis/calculus) principles of stochastics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students recognize the complexity of medical technology and can explain, which methods are appropriate to solve a problem at hand.
Skills	The students are able to analyze and solve problems in medical technology.
Personal Competence	
Social Competence	The students can define project aims and scope and organize the project as team work. They can present their results in an appropriate manner.
Autonomy	The students take responsibility for their tasks and coordinate their individual work with other group members. They deliver their work on time. They independently acquire additional knowledge by doing a specific literature research.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes, **Bonus** None, **Form** Group discussion, **Description**
Examination	Written elaboration
Examination duration and scale	approx. 8 pages, time frame: over the course of the semester
Assignment for the Following Curricula	Electrical Engineering: Specialisation Medical Technology: Elective Compulsory

Course L1096: Medical Technology Lab

Typ	Project-/problem-based Learning
Hrs/wk	6
CP	6
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Lecturer	Prof. Alexander Schlaefer
Language	DE/EN
Cycle	SoSe
Content	The actual project topic will be defined as part of the project.
Literature	Wird in der Veranstaltung bekannt gegeben.

Module M0811: Medical Imaging Systems

Courses

Title	Typ	Hrs/wk	CP
Medical Imaging Systems (L0819)	Lecture	4	6

Module Responsible	Dr. Michael Grass
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can: • Describe the system configuration and components of the main clinical imaging systems; • Explain how the system components and the overall system of the imaging systems function; • Explain and apply the physical processes that make imaging possible and use with the fundamental physical equations; • Name and describe the physical effects required to generate image contrasts; • Explain how spatial and temporal resolution can be influenced and how to characterize the images generated; • Explain which image reconstruction methods are used to generate images; Describe and explain the main clinical uses of the different systems.

Skills	Students are able to:
	• Explain the physical processes of images and assign to the systems the basic mathematical or physical equations required;
	  ◦ Calculate the parameters of imaging systems using the mathematical or physical equations;
	  ◦ Determine the influence of different system components on the spatial and temporal resolution of imaging systems;
	  ◦ Explain the importance of different imaging systems for a number of clinical applications;
	Select a suitable imaging system for an application.

Personal Competence	
Social Competence	none
Autonomy	Students can: • Understand which physical effects are used in medical imaging; • Decide independently for which clinical issue a measuring system can be used.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	
Assignment for the Following Curricula	Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Biomedical Engineering: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0819: Medical Imaging Systems	
Typ	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Dr. Michael Grass, Dr. Tim Nielsen, Dr. Sven Prevrhal, Frank Michael Weber
Language	DE
Cycle	SoSe
Content	
Literature	Primary book: 1. P. Suetens, "Fundamentals of Medical Imaging", Cambridge Press Secondary books: - A. Webb, "Introduction to Biomedical Imaging", IEEE Press 2003. - W.R. Hendee and E.R. Ritenour, "Medical Imaging Physics", Wiley-Liss, New York, 2002. - H. Morneburg (Edt), "Bildgebende Systeme für die medizinische Diagnostik", Erlangen: Siemens Publicis MCD Verlag, 1995. - O. Dössel, "Bildgebende Verfahren in der Medizin", Springer Verlag Berlin, 2000.

Module M1278: MED I: Introduction to Radiology and Radiation Therapy

Courses

Title	Typ	Hrs/wk	CP
Introduction to Radiology and Radiation Therapy (L0383)	Lecture	2	3

Module Responsible	Prof. Ulrich Carl
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	**Therapy** The students can distinguish different types of currently used equipment with respect to its use in radiation therapy. The students can explain treatment plans used in radiation therapy in interdisciplinary contexts (e.g. surgery, internal medicine). **The students can describe the patients' passage from their initial admittance through to follow-up care.** **Diagnostics** The students can illustrate the technical base concepts of projection radiography, including angiography and mammography, as well as sectional imaging techniques (CT, MRT, US). The students can explain the diagnostic as well as therapeutic use of imaging techniques, as well as the technical basis for those techniques. The students can choose the right treatment method depending on the patient's clinical history and needs. The student can explain the influence of technical errors on the imaging techniques. The student can draw the right conclusions based on the images' diagnostic findings or the error protocol.
Skills	**Therapy** The students can distinguish curative and palliative situations and motivate why they came to that conclusion. The students can develop adequate therapy concepts and relate it to the radiation biological aspects. The students can use the therapeutic principle (effects vs adverse effects) The students can distinguish different kinds of radiation, can choose the best one depending on the situation (location of the tumor) and choose the energy needed in that situation (irradiation planning). The student can assess what an individual psychosocial service should look like (e.g. follow-up treatment, sports, social help groups, self-help groups, social services, psycho-oncology). **Diagnostics** The students can suggest solutions for repairs of imaging instrumentation after having done error analyses. The students can classify results of imaging techniques according to different groups of diseases based on their knowledge of anatomy, pathology and pathophysiology.
Personal Competence	
Social Competence	The students can assess the special social situation of tumor patients and interact with them in a professional way. The students are aware of the special, often fear-dominated behavior of sick people caused by diagnostic and therapeutic measures and can meet them appropriately.
Autonomy	The students can apply their new knowledge and skills to a concrete therapy case. The students can introduce younger students to the clinical daily routine. The students are able to access anatomical knowledge by themselves, can participate competently in conversations on the topic and acquire the relevant knowledge themselves.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	General Engineering Science (German program): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (German program): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory General Engineering Science (English program): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (English program): Specialisation Biomedical Engineering: Compulsory

	General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory Mechanical Engineering: Specialisation Biomechanics: Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0383: Introduction to Radiology and Radiation Therapy	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ulrich Carl, Prof. Thomas Vestring
Language	DE
Cycle	SoSe
Content	The students will be given an understanding of the technological possibilities in the field of medical imaging, interventional radiology and radiation therapy/radiation oncology. It is assumed, that students in the beginning of the course have heard the word “X-ray” at best. It will be distinguished between the two arms of diagnostic (Prof. Dr. med. Thomas Vestring) and therapeutic (Prof. Dr. med. Ulrich Carl) use of X-rays. Both arms depend on special big units, which determine a predefined sequence in their respective departments
Literature	• "Technik der medizinischen Radiologie" von T. + J. Laubenberg – 7. Auflage – Deutscher Ärzteverlag – erschienen 1999 • "Klinische Strahlenbiologie" von Th. Herrmann, M. Baumann und W. Dörr – 4. Auflage - Verlag Urban & Fischer – erschienen 02.03.2006 ISBN: 978-3-437-23960-1 • "Strahlentherapie und Onkologie für MTA-R" von R. Sauer – 5. Auflage 2003 - Verlag Urban & Schwarzenberg – erschienen 08.12.2009 ISBN: 978-3-437-47501-6 • "Taschenatlas der Physiologie" von S. Silbernagel und A. Despopoulus- 8. Auflage – Georg Thieme Verlag - erschienen 19.09.2012 ISBN: 978-3-13-567708-8 • "Der Körper des Menschen " von A. Faller u. M. Schünke - 16. Auflage 2004 – Georg Thieme Verlag – erschienen 18.07.2012 ISBN: 978-3-13-329716-5 • „Praxismanual Strahlentherapie“ von Stöver / Feyer – 1. Auflage - Springer-Verlag GmbH – erschienen 02.06.2000

Module M1277: MED I: Introduction to Anatomy

Courses

Title	Typ	Hrs/wk	CP
Introduction to Anatomy (L0384)	Lecture	2	3

Module Responsible	Prof. Udo Schumacher
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can describe basal structures and functions of internal organs and the musculoskeletal system. The students can describe the basic macroscopy and microscopy of those systems.
Skills	The students can recognize the relationship between given anatomical facts and the development of some common diseases; they can explain the relevance of structures and their functions in the context of widespread diseases.
Personal Competence	
Social Competence	The students can participate in current discussions in biomedical research and medicine on a professional level.
Autonomy	The students are able to access anatomical knowledge by themselves, can participate in conversations on the topic and acquire the relevant knowledge themselves.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	General Engineering Science (German program): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (German program): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory General Engineering Science (English program): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (English program): Specialisation Biomedical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory Mechanical Engineering: Specialisation Biomechanics: Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0384: Introduction to Anatomy	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Tobias Lange
Language	DE
Cycle	SoSe
Content	**General Anatomy** **1st week: The Eucaryote Cell** **2nd week: The Tissues** **3rd week: Cell Cycle, Basics in Development** **4th week: Musculoskeletal System** **5th week: Cardiovascular System** **6th week: Respiratory System** **7th week: Genito-urinary System** **8th week: Immune system** **9th week: Digestive System I** **10th week: Digestive System II** **11th week: Endocrine System** **12th week: Nervous System** **13th week: Exam**
Literature	Adolf Faller/Michael Schünke, Der Körper des Menschen, 16. Auflage, Thieme Verlag Stuttgart, 2012

Module M1280: MED II: Introduction to Physiology

Courses

Title	Typ	Hrs/wk	CP
Introduction to Physiology (L0385)	Lecture	2	3

Module Responsible	Dr. Roger Zimmermann
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can • describe the basics of the energy metabolism; • describe physiological relations in selected fields of muscle, heart/circulation, neuro- and sensory physiology.
Skills	The students can describe the effects of basic bodily functions (sensory, transmission and processing of information, development of forces and vital functions) and relate them to similar technical systems.
Personal Competence	
Social Competence	The students can conduct discussions in research and medicine on a technical level. The students can find solutions to problems in the field of physiology, both analytical and metrological.
Autonomy	The students can derive answers to questions arising in the course and other physiological areas, using technical literature, by themselves.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Written exam
Examination duration and scale	60 minutes
Assignment for the Following Curricula	General Engineering Science (German program): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (German program): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory General Engineering Science (English program): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (English program): Specialisation Biomedical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory Mechanical Engineering: Specialisation Biomechanics: Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0385: Introduction to Physiology

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Gerhard Engler
Language	DE
Cycle	SoSe
Content	
Literature	Taschenatlas der Physiologie, Silbernagl Despopoulos, ISBN 978-3-135-67707-1, Thieme Repetitorium Physiologie, Speckmann, ISBN 978-3-437-42321-5, Elsevier

Module M0845: Feedback Control in Medical Technology

Courses

Title	Typ	Hrs/wk	CP
Feedback Control in Medical Technology (L0664)	Lecture	2	3

Module Responsible	Johannes Kreuzer
Admission Requirements	None
Recommended Previous Knowledge	Basics in Control, Basics in Physiology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The lecture will introduce into the fascinating area of medical technology with the engineering point of view. Fundamentals in human physiology will be similarly introduced like knowledge in control theory. Internal control loops of the human body will be discussed in the same way like the design of external closed loop system fo example in for anesthesia control. The handling of PID controllers and modern controller like predictive controller or fuzzy controller or neural networks will be illustrated. The operation of simple equivalent circuits will be discussed.
Skills	Application of modeling, identification, control technology in the field of medical technology.
Personal Competence	
Social Competence	Students can develop solutions to specific problems in small groups and present their results (e.g. during project week)
Autonomy	Students are able to find necessary literature and to set it into the context of the lecture. They are able to continuously evaluate their knowledge and to take control of their learning process. They can combine knowledge from different courses to form a consistent whole.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory

Course L0664: Feedback Control in Medical Technology

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner, Johannes Kreuzer, Christian Neuhaus
Language	DE
Cycle	SoSe
Content	Taking an engineering point of view, the lecture is structured as follows. • Introduction to the topic with selected examples • Physiology - introduction and overview • Regeneration of functions of the cardiovascular system • Regeneration of the respiratory functions • Closed loop control in anesthesia • regeneration of kidney and liver functions • regeneration of motorize function/ rehabilitation engineering • navigation systems and robotic in medicine The lecture will use knowledge from modeling, simulation and controller design and MATLAB and SIMULINK will be used.
Literature	Silbernagel/Depopoulos: Taschenatlas der Physiologie, Thieme Verlag Stuttgart Werner: Kooperative und autonome Systeme der Medizintechnik, Oldenburg Verlag M.C.K.Khoo:“Physiological Control System“, IEEE Press, 2000

Module M1325: Seminar Medical Technology

Courses

Title	Typ	Hrs/wk	CP
Seminar Medical Technology (L1830)	Seminar	2	2

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	Engineering / Mathematics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Review of a recent scientific publication
Skills	Reviewing of a scientific publications
Personal Competence	
Social Competence	presentation skills
Autonomy	Consider the publication in the context of the student's knowledge
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	20-30 minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Medical Technology: Elective Compulsory

Course L1830: Seminar Medical Technology

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe/SoSe
Content	We are considering recent scientific publications in the field of medical technology. Students will review a paper and discuss it's merits in the context of the state of the art. The key methods and results will be presented in a talk. Students will critically acclaim the authors contribution.
Literature	TBD

Module M0623: Intelligent Systems in Medicine

Courses

Title	Typ	Hrs/wk	CP
Intelligent Systems in Medicine (L0331)	Lecture	2	3
Intelligent Systems in Medicine (L0334)	Project Seminar	2	2
Intelligent Systems in Medicine (L0333)	Recitation Section (small)	1	1

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	• principles of math (algebra, analysis/calculus) • principles of stochastics • principles of programming, Java/C++ and R/Matlab • advanced programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to analyze and solve clinical treatment planning and decision support problems using methods for search, optimization, and planning. They are able to explain methods for classification and their respective advantages and disadvantages in clinical contexts. The students can compare different methods for representing medical knowledge. They can evaluate methods in the context of clinical data and explain challenges due to the clinical nature of the data and its acquisition and due to privacy and safety requirements.
Skills	The students can give reasons for selecting and adapting methods for classification, regression, and prediction. They can assess the methods based on actual patient data and evaluate the implemented methods.
Personal Competence	
Social Competence	The students discuss the results of other groups, provide helpful feedback and can incoorporate feedback into their work.
Autonomy	The students can reflect their knowledge and document the results of their work. They can present the results in an appropriate manner.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 10 % / Written elaboration Yes / 10 % / Presentation
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0331: Intelligent Systems in Medicine

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	- methods for search, optimization, planning, classification, regression and prediction in a clinical context - representation of medical knowledge - understanding challenges due to clinical and patient related data and data acquisition The students will work in groups to apply the methods introduced during the lecture using problem based learning.
Literature	Russel & Norvig: Artificial Intelligence: a Modern Approach, 2012 Berner: Clinical Decision Support Systems: Theory and Practice, 2007 Greenes: Clinical Decision Support: The Road Ahead, 2007 Further literature will be given in the lecture

Course L0334: Intelligent Systems in Medicine	
Typ	Project Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0333: Intelligent Systems in Medicine	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1249: Numerical Methods for Medical Imaging

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Numerical Methods for Medical Imaging (L1694)	Lecture	2	3
Numerical Methods for Medical Imaging (L1695)	Recitation Section (small)	2	3

Module Responsible	Prof. Tobias Knopp
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1694: Numerical Methods for Medical Imaging

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE
Cycle	WiSe
Content	
Literature	**Bildgebende Verfahren in der Medizin**; O. Dössel; Springer, Berlin, 2000 **Bildgebende Systeme für die medizinische Diagnostik**; H. Morneburg (Hrsg.); Publicis MCD, München, 1995 **Introduction to the Mathematics of Medical Imaging**; C. L.Epstein; Siam, Philadelphia, 2008 **Medical Image Processing, Reconstruction and Restoration**; J. Jan; Taylor and Francis, Boca Raton, 2006 **Principles of Magnetic Resonance Imaging**; Z.-P. Liang and P. C. Lauterbur; IEEE Press, New York, 1999

Course L1695: Numerical Methods for Medical Imaging

Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1279: MED II: Introduction to Biochemistry and Molecular Biology

Courses

Title	Typ	Hrs/wk	CP
Introduction to Biochemistry and Molecular Biology (L0386)	Lecture	2	3

Module Responsible	Prof. Hans-Jürgen Kreienkamp
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can • describe basic biomolecules; • explain how genetic information is coded in the DNA; • explain the connection between DNA and proteins;
Skills	The students can • recognize the importance of molecular parameters for the course of a disease; • describe selected molecular-diagnostic procedures; • explain the relevance of these procedures for some diseases
Personal Competence	
Social Competence	The students can participate in discussions in research and medicine on a technical level.
Autonomy	The students can develop understanding of topics from the course, using technical literature, by themselves.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Written exam
Examination duration and scale	60 minutes
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Biomedical Engineering: Compulsory General Engineering Science (German program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechanical Engineering, Focus Biomechanics: Compulsory General Engineering Science (English program, 7 semester): Specialisation Biomedical Engineering: Compulsory Mechanical Engineering: Specialisation Biomechanics: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory

Course L0386: Introduction to Biochemistry and Molecular Biology

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Hans-Jürgen Kreienkamp
Language	DE
Cycle	WiSe
Content	
Literature	Müller-Esterl, Biochemie, Spektrum Verlag, 2010; 2. Auflage Löffler, Basiswissen Biochemie, 7. Auflage, Springer, 2008

Module M0768: Microsystems Technology in Theory and Practice

Courses

Title	Typ	Hrs/wk	CP
Microsystems Technology (L0724)	Lecture	2	4
Microsystems Technology (L0725)	Project-/problem-based Learning	2	2

Module Responsible	Prof. Hoc Khiem Trieu
Admission Requirements	None
Recommended Previous Knowledge	Basics in physics, chemistry, mechanics and semiconductor technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able • to present and to explain current fabrication techniques for microstructures and especially methods for the fabrication of microsensors and microactuators, as well as the integration thereof in more complex systems • to explain in details operation principles of microsensors and microactuators and • to discuss the potential and limitation of microsystems in application.
Skills	Students are capable • to analyze the feasibility of microsystems, • to develop process flows for the fabrication of microstructures and • to apply them.
Personal Competence	
Social Competence	Students are able to prepare and perform their lab experiments in team work as well as to present and discuss the results in front of audience.
Autonomy	None
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Subject theoretical and practical work / Studierenden führen in Kleingruppen ein Laborpraktikum durch. Jede Gruppe präsentiert und diskutiert die Theorie sowie die Ergebniise ihrer Labortätigkeit. vor dem gesamten Kurs.
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L0725: Microsystems Technology	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0792: Reserach Project in Medical Technology

Courses			
Title	**Typ**	**Hrs/wk**	**CP**

Module Responsible	Dozenten des SD E
Admission Requirements	None
Recommended Previous Knowledge	Advanced state of knowledge in the electrical engineering master program
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know current research topics oft institutes engaged in their specialization. They can name the fundamental scientific methods used for doing related reserach.
Skills	Students are capable of completing a small, independent sub-project of currently ongoing research projects in the institutes engaged in their specialization. Students can justify and explain their approach for problem solving, they can draw conclusions from their results, and then can find new ways and methods for their work. Students are capable of comparing and assessing alterantive approaches with their own with regard to given criteria.
Personal Competence	
Social Competence	Students are able to discuss their work progress with research assistants of the supervising institute . They are capable of presenting their results in front of a professional audience.
Autonomy	Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research project for themselves. They are able to develop the necessary understanding and problem solving methods.
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Study work
Examination duration and scale	acc. to ASPO
Assignment for the Following Curricula	Electrical Engineering: Specialisation Medical Technology: Compulsory

Module M0550: Digital Image Analysis

Courses

Title	Typ	Hrs/wk	CP
Digital Image Analysis (L0126)	Lecture	4	6

Module Responsible	Prof. Rolf-Rainer Grigat
Admission Requirements	None
Recommended Previous Knowledge	System theory of one-dimensional signals (convolution and correlation, sampling theory, interpolation and decimation, Fourier transform, linear time-invariant systems), linear algebra (Eigenvalue decomposition, SVD), basic stochastics and statistics (expectation values, influence of sample size, correlation and covariance, normal distribution and its parameters), basics of Matlab, basics in optics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can • Describe imaging processes • Depict the physics of sensorics • Explain linear and non-linear filtering of signals • Establish interdisciplinary connections in the subject area and arrange them in their context • Interpret effects of the most important classes of imaging sensors and displays using mathematical methods and physical models.
Skills	Students are able to • Use highly sophisticated methods and procedures of the subject area • Identify problems and develop and implement creative solutions. Students can solve simple arithmetical problems relating to the specification and design of image processing and image analysis systems. Students are able to assess different solution approaches in multidimensional decision-making areas. Students can undertake a prototypical analysis of processes in Matlab.
Personal Competence	
Social Competence	k.A.
Autonomy	Students can solve image analysis tasks independently using the relevant literature.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 Minutes, Content of Lecture and materials in StudIP
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory

Course L0126: Digital Image Analysis	
Typ	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Rolf-Rainer Grigat
Language	EN
Cycle	WiSe
Content	• Image representation, definition of images and volume data sets, illumination, radiometry, multispectral imaging, reflectivities, shape from shading • Perception of luminance and color, color spaces and transforms, color matching functions, human visual system, color appearance models • imaging sensors (CMOS, CCD, HDR, X-ray, IR), sensor characterization(EMVA1288), lenses and optics • spatio-temporal sampling (interpolation, decimation, aliasing, leakage, moiré, flicker, apertures) • features (filters, edge detection, morphology, invariance, statistical features, texture) • optical flow (variational methods, quadratic optimization, Euler-Lagrange equations) • segmentation (distance, region growing, cluster analysis, active contours, level sets, energy minimization and graph cuts) • registration (distance and similarity, variational calculus, iterative closest points)
Literature	Bredies/Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 Wedel/Cremers, Stereo Scene Flow for 3D Motion Analysis, Springer 2011 Handels, Medizinische Bildverarbeitung, Vieweg, 2000 Pratt, Digital Image Processing, Wiley, 2001 Jain, Fundamentals of Digital Image Processing, Prentice Hall, 1989

Module M0921: Electronic Circuits for Medical Applications

Courses

Title	Typ	Hrs/wk	CP
Electronic Circuits for Medical Applications (L0696)	Lecture	2	3
Electronic Circuits for Medical Applications (L1056)	Recitation Section (small)	1	2
Electronic Circuits for Medical Applications (L1408)	Practical Course	1	1

Module Responsible	Prof. Matthias Kuhl
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of electrical engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the basic functionality of the information transfer by the central nervous system • Students are able to explain the build-up of an action potential and its propagation along an axon • Students can exemplify the communication between neurons and electronic devices • Students can describe the special features of low-noise amplifiers for medical applications • Students can explain the functions of prostheses, e. g. an artificial hand • Students are able to discuss the potential and limitations of cochlea implants and artificial eyes
Skills	• Students can calculate the time dependent voltage behavior of an action potential • Students can give scenarios for further improvement of low-noise and low-power signal acquisition. • Students can develop the block diagrams of prosthetic systems • Students can define the building blocks of electronic systems for an artificial eye.
Personal Competence	
Social Competence	• Students are trained to solve problems in the field of medical electronics in teams together with experts with different professional background. • Students are able to recognize their specific limitations, so that they can ask for assistance to the right time. • Students can document their work in a clear manner and communicate their results in a way that others can be involved whenever it is necessary
Autonomy	• Students are able to realistically judge the status of their knowledge and to define actions for improvements when necessary. • Students can break down their work in appropriate work packages and schedule their work in a realistic way. • Students can handle the complex data structures of bioelectrical experiments without needing support. • Students are able to act in a responsible manner in all cases and situations of experimental work.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Subject theoretical and practical work / No / None / Excercises /
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0696: Electronic Circuits for Medical Applications	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl
Language	EN
Cycle	WiSe
Content	• Market for medical instruments • Membrane potential, action potential, sodium-potassium pump • Information transfer by the central nervous system • Interface tissue - electrode • Amplifiers for medical applications, analog-digital converters • Examples for electronic implants • Artificial eye, cochlea implant
Literature	Kim E. Barret, Susan M. Barman, Scott Boitano and Heddwen L. Brooks Ganong's Review of Medical Physiology, 24nd Edition, McGraw Hill Lange, 2010 Tier- und Humanphysiologie: Eine Einführung von Werner A. Müller (Author), Stephan Frings (Author), 657 p., 4. editions, Springer, 2009 Robert F. Schmidt (Editor), Hans-Georg Schaible (Editor) Neuro- und Sinnesphysiologie (Springer-Lehrbuch) (Paper back), 488 p., Springer, 2006, 5. Edition, currently online only Russell K. Hobbie, Bradley J. Roth, Intermediate Physics for Medicine and Biology, Springer, 4th ed., 616 p., 2007 Vorlesungen der Universität Heidelberg zur Tier- und Humanphysiologie: http://www.sinnesphysiologie.de/gruvo03/gruvoin.htm Internet: http://butler.cc.tut.fi/~malmivuo/bem/bembook/

Course L1056: Electronic Circuits for Medical Applications	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Matthias Kuhl
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1408: Electronic Circuits for Medical Applications	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Matthias Kuhl
Language	EN
Cycle	WiSe
Content	• Market for medical instruments • Membrane potential, action potential, sodium-potassium pump • Information transfer by the central nervous system • Interface tissue - electrode • Amplifiers for medical applications, analog-digital converters • Examples for electronic implants • Artificial eye, cochlea implant
Literature	Kim E. Barret, Susan M. Barman, Scott Boitano and Heddwen L. Brooks Ganong's Review of Medical Physiology, 24nd Edition, McGraw Hill Lange, 2010 Tier- und Humanphysiologie: Eine Einführung von Werner A. Müller (Author), Stephan Frings (Author), 657 p., 4. editions, Springer, 2009 Robert F. Schmidt (Editor), Hans-Georg Schaible (Editor) Neuro- und Sinnesphysiologie (Springer-Lehrbuch) (Paper back), 488 p., Springer, 2006, 5. Edition, currently online only Russell K. Hobbie, Bradley J. Roth, Intermediate Physics for Medicine and Biology, Springer, 4th ed., 616 p., 2007 Vorlesungen der Universität Heidelberg zur Tier- und Humanphysiologie: http://www.sinnesphysiologie.de/gruvo03/gruvoin.htm Internet: http://butler.cc.tut.fi/~malmivuo/bem/bembook/

Specialization Modeling and Simulation

In this specialization students have the opportunity to select courses that focus on the areas of mathematical modeling, numerical techniques, computer aided engineering (CAE) and state-of- the-art simulation tools with application in electrical engineering. Students will learn to derive, implement, validate, and optimize numerical algorithms. Thereby students will obtain unique competencies at the interface between mathematics, computer science, and electrical engineering that are required for corresponding positions in industry and academia.

Module M0747: Microsystem Design

Courses

Title	Typ	Hrs/wk	CP
Microsystem Design (L0683)	Lecture	2	3
Microsystem Design (L0684)	Practical Course	3	3

Module Responsible	Prof. Manfred Kasper
Admission Requirements	None
Recommended Previous Knowledge	Mathematical Calculus, Linear Algebra, Microsystem Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about the most important and most common simulation and design methods used in microsystem design. The scientific background of finite element methods and the basic theory of these methods are known.
Skills	Students are able to apply simulation methods and commercial simulators in a goal oriented approach to complex design tasks. Students know to apply the theory in order achieve estimates of expected accuracy and can judge and verify the correctness of results. Students are able to develop a design approach even if only incomplete information about material data or constraints are available. Student can make use of approximate and reduced order models in a preliminary design stage or a system simulation.
Personal Competence	
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly. Students can develop and explain their solution approach and subdivide the design task to subproblems which are solved separately by group members.
Autonomy	Students are able to acquire particular knowledge using specialized literature and to integrate and associate this knowledge with other fields.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Written elaboration; **Description**
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0683: Microsystem Design	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Manfred Kasper
Language	EN
Cycle	SoSe
Content	Finite difference methods Approximation error Finite element method Order of convergence Error estimation, mesh refinement Makromodeling Reduced order modeling Black-box models System identification Multi-physics systems System simulation Levels of simulation, network simulation Transient problems Non-linear problems Introduction to Comsol Application to thermal, electric, electromagnetic, mechanical and fluidic problems
Literature	M. Kasper: Mikrosystementwurf, Springer (2000) S. Senturia: Microsystem Design, Kluwer (2001)

Course L0684: Microsystem Design	
Typ	Practical Course
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Manfred Kasper
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0692: Approximation and Stability

Courses

Title	Typ	Hrs/wk	CP
Approximation and Stability (L0487)	Lecture	3	4
Approximation and Stability (L0488)	Recitation Section (small)	1	2

Module Responsible	Prof. Marko Lindner
Admission Requirements	None
Recommended Previous Knowledge	• Linear Algebra: systems of linear equations, least squares problems, eigenvalues, singular values • Analysis: sequences, series, differentiation, integration
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • sketch and interrelate basic concepts of functional analysis (Hilbert space, operators), • name and understand concrete approximation methods, • name and explain basic stability theorems, • discuss spectral quantities, conditions numbers and methods of regularisation
Skills	Students are able to • apply basic results from functional analysis, • apply approximation methods, • apply stability theorems, • compute spectral quantities, • apply regularisation methods.
Personal Competence	
Social Competence	Students are able to solve specific problems in groups and to present their results appropriately (e.g. as a seminar presentation).
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: None; **Form**: Presentation; **Description**:
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation I. Numerics (TUHH): Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0487: Approximation and Stability	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Marko Lindner
Language	DE/EN
Cycle	SoSe
Content	This course is about solving the following basic problems of Linear Algebra, • systems of linear equations, • least squares problems, • eigenvalue problems but now in function spaces (i.e. vector spaces of infinite dimension) by a stable approximation of the problem in a space of finite dimension. **Contents:** • crash course on Hilbert spaces: metric, norm, scalar product, completeness • crash course on operators: boundedness, norm, compactness, projections • uniform vs. strong convergence, approximation methods • applicability and stability of approximation methods, Polski's theorem • Galerkin methods, collocation, spline interpolation, truncation • convolution and Toeplitz operators • crash course on C*-algebras • convergence of condition numbers • convergence of spectral quantities: spectrum, eigen values, singular values, pseudospectra • regularisation methods (truncated SVD, Tichonov)
Literature	• R. Hagen, S. Roch, B. Silbermann: C*-Algebras in Numerical Analysis • H. W. Alt: Lineare Funktionalanalysis • M. Lindner: Infinite matrices and their finite sections

Course L0488: Approximation and Stability	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Marko Lindner
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0653: High-Performance Computing

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Fundamentals of High-Performance Computing (L0242)	Lecture	2	3
Fundamentals of High-Performance Computing (L1416)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Thomas Rung
Admission Requirements	None
Recommended Previous Knowledge	• Basic knowledge in usage of modern IT environment • Programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to outline the fundamentals of numerical algorithms for high-performance computers by reference to modern hardware examples. Students can explain the relation between hard- and software aspects for the design of algorithms.
Skills	Student can perform a critical assesment of the computational efficiency of simulation approaches.
Personal Competence	
Social Competence	Students are able to develop and code algorithms in a team.
Autonomy	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	1.5h
Assignment for the Following Curricula	Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0242: Fundamentals of High-Performance Computing

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Thomas Rung
Language	DE/EN
Cycle	SoSe
Content	Fundamentals of modern hardware architectur, critical hard- & software aspects for efficient processing of exemplary algorithms, concepts for shared- and distributed-memory systems, implementations for accelerator hardware (GPGPUs)
Literature	1) Vortragsmaterialien und Problemanleitungen 2) G. Hager G. Wellein: Introduction to High Performance Computing for Scientists and Engineers CRC Computational Science Series, 2010

Course L1416: Fundamentals of High-Performance Computing

Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Thomas Rung
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0715: Solvers for Sparse Linear Systems

Courses

Title	Typ	Hrs/wk	CP
Solvers for Sparse Linear Systems (L0583)	Lecture	2	3
Solvers for Sparse Linear Systems (L0584)	Recitation Section (small)	2	3

Module Responsible	Prof. Sabine Le Borne
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I + II for Engineering students or Analysis & Lineare Algebra I + II for Technomathematicians • Programming experience in C
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can • list classical and modern iteration methods and their interrelationships, • repeat convergence statements for iteration methods, • explain aspects regarding the efficient implementation of iteration methods.
Skills	Students are able to • implement, test, and compare iterative methods, • analyse the convergence behaviour of iterative methods and, if applicable, compute congergence rates.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, • to work on complex problems over an extended period of time, • to assess their individual progess and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Computer Science: Specialisation Computational Mathematics: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation Computer Science: Elective Compulsory Computational Science and Engineering: Specialisation Mathematics & Engineering Science: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory

Course L0583: Solvers for Sparse Linear Systems

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne
Language	DE/EN
Cycle	SoSe
Content	1. Sparse systems: Orderings and storage formats, direct solvers 2. Classical methods: basic notions, convergence 3. Projection methods 4. Krylov space methods 5. Preconditioning (e.g. ILU) 6. Multigrid methods
Literature	1. Y. Saad, Iterative methods for sparse linear systems

Course L0584: Solvers for Sparse Linear Systems	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0935: Microcontroller Circuits: Implementation in Hardware and Software

Courses

Title	Typ	Hrs/wk	CP
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2

Module Responsible	Prof. Siegfried Rump
Admission Requirements	None
Recommended Previous Knowledge	lecture: Computer Architectures
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can describe parts and operation of a common family of microcontrollers. They know details about operations of CPUs, and they can transfer algorithms to machine code.
Skills	The students can design and use electronic circuits (digital with some analogue parts). Furthermore they are able to implement solutions of some tasks by way of assembler programming on these circuits.
Personal Competence	
Social Competence	Groups of two students work on special projects. The students have the skill to separate the project into smaller parts and to present the achieved results in an appropriate short talk.
Autonomy	The student can use, select and estimate suitable sources, which are available from information technology companies. They apply those findings to their projects.
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Written elaboration
Examination duration and scale	15 minutes + disputation
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	ATmega16A 8-bit Microcontroller with 16K Bytes In-System Programmable Flash - DATASHEET, Atmel Corporation 2014 Atmel AVR 8-bit Instruction Set Instruction Set Manual, Atmel Corporation 2016

Module M0714: Numerical Treatment of Ordinary Differential Equations

Courses

Title	Typ	Hrs/wk	CP
Numerical Treatment of Ordinary Differential Equations (L0576)	Lecture	2	3
Numerical Treatment of Ordinary Differential Equations (L0582)	Recitation Section (small)	2	3

Module Responsible	Prof. Sabine Le Borne
Admission Requirements	None
Recommended Previous Knowledge	• Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis & Lineare Algebra I + II sowie Analysis III für Technomathematiker • Basic MATLAB knowledge
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • list numerical methods for the solution of ordinary differential equations and explain their core ideas, • repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem), • explain aspects regarding the practical execution of a method. • select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results
Skills	Students are able to • implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations, • to justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm, • for a given problem, develop a suitable solution approach, if necessary by the composition of several algorithms, to execute this approach and to critically evaluate the results.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, • to assess their individual progress and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation l. Numerics (TUHH): Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0576: Numerical Treatment of Ordinary Differential Equations	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne, Dr. Christian Seifert, Dr. Patricio Farrell
Language	DE/EN
Cycle	SoSe
Content	Numerical methods for Initial Value Problems • single step methods • multistep methods • stiff problems • differential algebraic equations (DAE) of index 1 Numerical methods for Boundary Value Problems • multiple shooting method • difference methods • variational methods
Literature	• E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems • E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems

Course L0582: Numerical Treatment of Ordinary Differential Equations	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne, Dr. Patricio Farrell
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1316: Research Project in Modeling and Simulation

Courses			
Title	**Typ**	**Hrs/wk**	**CP**

Module Responsible	Dozenten des SD E
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Study work
Examination duration and scale	acc. to ASPO
Assignment for the Following Curricula	Electrical Engineering: Specialisation Modeling and Simulation: Compulsory

Module M0716: Hierarchical Algorithms

Courses

Title	Typ	Hrs/wk	CP
Hierarchical Algorithms (L0585)	Lecture	2	3
Hierarchical Algorithms (L0586)	Recitation Section (small)	2	3

Module Responsible	Prof. Sabine Le Borne
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I, II, III for Engineering students (german or english) or Analysis & Linear Algebra I + II as well as Analysis III for Technomathematicians • Programming experience in C
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • name representatives of hierarchical algorithms and list their characteristics, • explain construction techniques for hierarchical algorithms, • discuss aspects regarding the efficient implementation of hierarchical algorithms.
Skills	Students are able to • implement the hierarchical algorithms discussed in the lecture, • analyse the storage and computational complexities of the algorithms, • adapt algorithms to problem settings of various applications and thus develop problem adapted variants.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, • to work on complex problems over an extended period of time, • to assess their individual progess and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation III. Mathematics: Elective Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation II. Modelling and Simulation of Complex Systems (TUHH): Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0585: Hierarchical Algorithms

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne
Language	DE/EN
Cycle	WiSe
Content	• Low rank matrices • Separable expansions • Hierarchical matrix partitions • Hierarchical matrices • Formatted matrix operations • Applications • Additional topics (e.g. H2 matrices, matrix functions, tensor products)
Literature	W. Hackbusch: Hierarchische Matrizen: Algorithmen und Analysis

Course L0586: Hierarchical Algorithms	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0586: Efficient Algorithms

Courses

Title	Typ	Hrs/wk	CP
Efficient Algorithms (L0120)	Lecture	2	3
Efficient Algorithms (L1207)	Recitation Section (small)	2	3

Module Responsible	Prof. Siegfried Rump
Admission Requirements	None
Recommended Previous Knowledge	Programming in Matlab and/or C Basic knowledge in discrete mathematics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to explain the basic theory and methods of network algorithms and in particular their data structures. They are able to analyze the computational behavior and computing time of linear programming algorithms as well network algorithms. Moreover the students can distinguish between efficiently solvable and NP-hard problems.
Skills	The students are able to analyze complex tasks and can determine possibilities to transform them into networking algorithms. In particular they can efficiently implement basic algorithms and data structures of LP- and network algorithms and identify possible weaknesses. They are able to distinguish between different efficient data structures and are able to use them appropriately.
Personal Competence	
Social Competence	The students have the skills to solve problems together in small groups and to present the achieved results in an appropriate manner.
Autonomy	The students are able to retrieve necessary informations from the given literature and to combine them with the topics of the lecture. Throughout the lecture they can check their abilities and knowledge on the basis of given exercises and test questions providing an aid to optimize their learning process.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory

Course L0120: Efficient Algorithms

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe
Content	- Linear Programming - Data structures - Leftist heaps - Minimum spanning tree - Shortest path - Maximum flow - NP-hard problems via max-cut
Literature	R. E. Tarjan: Data Structures and Network Algorithms. CBMS 44, Society for Industrial and Applied Mathematics, Philadelphia, PA, 1983. Wesley, 2011 http://algs4.cs.princeton.edu/home/ V. Chvátal, ``Linear Programming'', Freeman, New York, 1983.

Course L1207: Efficient Algorithms	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0881: Mathematical Image Processing

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Mathematical Image Processing (L0991)	Lecture	3	4
Mathematical Image Processing (L0992)	Recitation Section (small)	1	2

Module Responsible	Prof. Marko Lindner
Admission Requirements	None
Recommended Previous Knowledge	• Analysis: partial derivatives, gradient, directional derivative • Linear Algebra: eigenvalues, least squares solution of a linear system
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • characterize and compare diffusion equations • explain elementary methods of image processing • explain methods of image segmentation and registration • sketch and interrelate basic concepts of functional analysis
Skills	Students are able to • implement and apply elementary methods of image processing • explain and apply modern methods of image processing
Personal Competence	
Social Competence	Students are able to work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge) and to explain theoretical foundations.
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation III. Mathematics: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0991: Mathematical Image Processing

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Marko Lindner, Dr. Christian Seifert
Language	DE/EN
Cycle	WiSe
Content	• basic methods of image processing • smoothing filters • the diffusion / heat equation • variational formulations in image processing • edge detection • de-convolution • inpainting • image segmentation • image registration
Literature	Bredies/Lorenz: Mathematische Bildverarbeitung

Course L0992: Mathematical Image Processing	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Marko Lindner
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0720: Matrix Algorithms

Courses

Title	Typ	Hrs/wk	CP
Matrix Algorithms (L0984)	Lecture	2	3
Matrix Algorithms (L0985)	Recitation Section (small)	2	3

Module Responsible	Dr. Jens-Peter Zemke
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I - III • Numerical Mathematics 1/ Numerics • Basic knowledge of the programming languages Matlab and C
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to 1. name, state and classify state-of-the-art Krylov subspace methods for the solution of the core problems of the engineering sciences, namely, eigenvalue problems, solution of linear systems, and model reduction; 2. state approaches for the solution of matrix equations (Sylvester, Lyapunov, Riccati).
Skills	Students are capable to 1. implement and assess basic Krylov subspace methods for the solution of eigenvalue problems, linear systems, and model reduction; 2. assess methods used in modern software with respect to computing time, stability, and domain of applicability; 3. adapt the approaches learned to new, unknown types of problem.
Personal Competence	
Social Competence	Students can • develop and document joint solutions in small teams; • form groups to further develop the ideas and transfer them to other areas of applicability; • form a team to develop, build, and advance a software library.
Autonomy	Students are able to • correctly assess the time and effort of self-defined work; • assess whether the supporting theoretical and practical excercises are better solved individually or in a team; • define test problems for testing and expanding the methods; • assess their individual progess and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	25 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation II. Modelling and Simulation of Complex Systems (TUHH): Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory

Course L0984: Matrix Algorithms	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	• Part A: Krylov Subspace Methods: ◦ Basics (derivation, basis, Ritz, OR, MR) ◦ Arnoldi-based methods (Arnoldi, GMRes) ◦ Lanczos-based methods (Lanczos, CG, BiCG, QMR, SymmLQ, PvL) ◦ Sonneveld-based methods (IDR, BiCGStab, TFQMR, IDR(s)) • Part B: Matrix Equations: ◦ Sylvester Equation ◦ Lyapunov Equation ◦ Algebraic Riccati Equation
Literature	Skript

Course L0985: Matrix Algorithms	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Jens-Peter Zemke
Language	DE/EN
Cycle	WiSe
Content	
Literature	Siehe korrespondierende Vorlesung

Module M1249: Numerical Methods for Medical Imaging

Courses

Title	Typ	Hrs/wk	CP
Numerical Methods for Medical Imaging (L1694)	Lecture	2	3
Numerical Methods for Medical Imaging (L1695)	Recitation Section (small)	2	3

Module Responsible	Prof. Tobias Knopp
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1694: Numerical Methods for Medical Imaging

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE
Cycle	WiSe
Content	
Literature	**Bildgebende Verfahren in der Medizin**; O. Dössel; Springer, Berlin, 2000 **Bildgebende Systeme für die medizinische Diagnostik**; H. Morneburg (Hrsg.); Publicis MCD, München, 1995 **Introduction to the Mathematics of Medical Imaging**; C. L.Epstein; Siam, Philadelphia, 2008 **Medical Image Processing, Reconstruction and Restoration**; J. Jan; Taylor and Francis, Boca Raton, 2006 **Principles of Magnetic Resonance Imaging**; Z.-P. Liang and P. C. Lauterbur; IEEE Press, New York, 1999

Course L1695: Numerical Methods for Medical Imaging

Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization Information and Communication Systems

This specialization offers a wide range of topics with respect to various concepts of telecommunications, wireless and wired communication systems as well as methods of digital signal processing. Students are able to understand the characteristics of transmission channels and principles of wireless systems in detail. Moreover, they acquire a profound knowledge about fundamentals, structures and modelling of communication networks. In addition, know-how on digital speech, audio and image processing is provided. As a result, the students will have the skills to analyze, design and optimize all aspects of a communication system. In today’s information age, this expertise is of paramount importance for positions in industry and academia.

Module M0551: Pattern Recognition and Data Compression

Courses

Title	**Typ**	**Hrs/wk**	**CP**
Pattern Recognition and Data Compression (L0128)	Lecture	4	6

Module Responsible	Prof. Rolf-Rainer Grigat
Admission Requirements	None
Recommended Previous Knowledge	Linear algebra (including PCA, unitary transforms), stochastics and statistics, binary arithmetics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can name the basic concepts of pattern recognition and data compression. Students are able to discuss logical connections between the concepts covered in the course and to explain them by means of examples.
Skills	Students can apply statistical methods to classification problems in pattern recognition and to prediction in data compression. On a sound theoretical and methodical basis they can analyze characteristic value assignments and classifications and describe data compression and video signal coding. They are able to use highly sophisticated methods and processes of the subject area. Students are capable of assessing different solution approaches in multidimensional decision-making areas.
Personal Competence	
Social Competence	k.A.
Autonomy	Students are capable of identifying problems independently and of solving them scientifically, using the methods they have learnt.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 Minutes, Content of Lecture and materials in StudIP
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0128: Pattern Recognition and Data Compression	
Typ	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Rolf-Rainer Grigat
Language	EN
Cycle	SoSe
Content	Structure of a pattern recognition system, statistical decision theory, classification based on statistical models, polynomial regression, dimension reduction, multilayer perceptron regression, radial basis functions, support vector machines, unsupervised learning and clustering, algorithm-independent machine learning, mixture models and EM, adaptive basis function models and boosting, Markov random fields Information, entropy, redundancy, mutual information, Markov processes, basic coding schemes (code length, run length coding, prefix-free codes), entropy coding (Huffman, arithmetic coding), dictionary coding (LZ77/Deflate/LZMA2, LZ78/LZW), prediction, DPCM, CALIC, quantization (scalar and vector quantization), transform coding, prediction, decorrelation (DPCM, DCT, hybrid DCT, JPEG, JPEG-LS), motion estimation, subband coding, wavelets, HEVC (H.265,MPEG-H)
Literature	Schürmann: Pattern Classification, Wiley 1996 Murphy, Machine Learning, MIT Press, 2012 Barber, Bayesian Reasoning and Machine Learning, Cambridge, 2012 Duda, Hart, Stork: Pattern Classification, Wiley, 2001 Bishop: Pattern Recognition and Machine Learning, Springer 2006 Salomon, Data Compression, the Complete Reference, Springer, 2000 Sayood, Introduction to Data Compression, Morgan Kaufmann, 2006 Ohm, Multimedia Communication Technology, Springer, 2004 Solari, Digital video and audio compression, McGraw-Hill, 1997 Tekalp, Digital Video Processing, Prentice Hall, 1995

Module M0637: Advanced Concepts of Wireless Communications

Courses

Title	Typ	Hrs/wk	CP
Advanced Concepts of Wireless Communications (L0297)	Lecture	3	4
Advanced Concepts of Wireless Communications (L0298)	Recitation Section (large)	1	2

Module Responsible	Dr. Rainer Grünheid
Admission Requirements	None
Recommended Previous Knowledge	• Lecture "Signals and Systems" • Lecture "Fundamentals of Telecommunications and Stochastic Processes" • Lecture "Digital Communications"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain the general as well as advanced principles and techniques that are applied to wireless communications. They understand the properties of wireless channels and the corresponding mathematical description. Furthermore, students are able to explain the physical layer of wireless transmission systems. In this context, they are proficient in the concepts of multicarrier transmission (OFDM), modulation, error control coding, channel estimation and multi-antenna techniques (MIMO). Students can also explain methods of multiple access. On the example of contemporary communication systems (UMTS, LTE) they can put the learnt content into a larger context.
Skills	Using the acquired knowledge, students are able to understand the design of current and future wireless systems. Moreover, given certain constraints, they can choose appropriate parameter settings of communication systems. Students are also able to assess the suitability of technical concepts for a given application.
Personal Competence	
Social Competence	Students can jointly elaborate tasks in small groups and present their results in an adequate fashion.
Autonomy	Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. They can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker questions, exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topics of other lectures, e.g., "Fundamentals of Communications and Stochastic Processes" and "Digital Communications".
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes; scope: content of lecture and exercise
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory

Course L0297: Advanced Concepts of Wireless Communications	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Dr. Rainer Grünheid
Language	EN
Cycle	SoSe
Content	The lecture deals with technical principles and related concepts of mobile communications. In this context, the main focus is put on the physical and data link layer of the ISO-OSI stack. In the lecture, the transmission medium, i.e., the mobile radio channel, serves as the starting point of all considerations. The characteristics and the mathematical descriptions of the radio channel are discussed in detail. Subsequently, various physical layer aspects of wireless transmission are covered, such as channel coding, modulation/demodulation, channel estimation, synchronization, and equalization. Moreover, the different uses of multiple antennas at the transmitter and receiver, known as MIMO techniques, are described. Besides these physical layer topics, concepts of multiple access schemes in a cellular network are outlined. In order to illustrate the above-mentioned technical solutions, the lecture will also provide a system view, highlighting the basics of some contemporary wireless systems, including UMTS/HSPA, LTE, LTE Advanced, and WiMAX.
Literature	John G. Proakis, Masoud Salehi: Digital Communications. 5th Edition, Irwin/McGraw Hill, 2007 David Tse, Pramod Viswanath: Fundamentals of Wireless Communication. Cambridge, 2005 Bernard Sklar: Digital Communications: Fundamentals and Applications. 2nd Edition, Pearson, 2013 Stefani Sesia, Issam Toufik, Matthew Baker: LTE - The UMTS Long Term Evolution. Second Edition, Wiley, 2011

Course L0298: Advanced Concepts of Wireless Communications	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr. Rainer Grünheid
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1318: Wireless Sensor Networks

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Wireless Sensor Networks (L1815)	Lecture	2	2
Wireless Sensor Networks (L1816)	Recitation Section (small)	1	1
Wireless Sensor Networks: Project (L1819)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Bernd-Christian Renner
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L1815: Wireless Sensor Networks

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Bernd-Christian Renner
Language	EN
Cycle	SoSe
Content	
Literature	

Course L1816: Wireless Sensor Networks

Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Bernd-Christian Renner
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1819: Wireless Sensor Networks: Project	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bernd-Christian Renner
Language	EN
Cycle	SoSe
Content	The PrBL course part will be performed in small groups of students. Topics are from the field of wireless sensor networks and are loosely related to the lecture contents. Project descriptions and goals are provided but have to be solved by the students as follow: 1. Group meeting, creation of working plan and milestones 2. kick-off presentation (during lecture) 3. free working 4. poster creation and presentation Throughout the semester, there will be meetings with the supervisor on a regular basis (weekly or biweekly). Details about the topics and course organization will be provided in the first lecture. Please note that the number of participants is limited due to the available capacity (rooms, equipment, supervisors).
Literature	Will be provided individually

Module M0673: Information Theory and Coding

Courses

Title	Typ	Hrs/wk	CP
Information Theory and Coding (L0436)	Lecture	3	4
Information Theory and Coding (L0438)	Recitation Section (large)	1	2

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics 1-3 • Probability theory and random processes • Basic knowledge of communications engineering (e.g. from lecture "Fundamentals of Communications and Random Processes")
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know the basic definitions for quantification of information in the sense of information theory. They know Shannon's source coding theorem and channel coding theorem and are able to determine theoretical limits of data compression and error-free data transmission over noisy channels. They understand the principles of source coding as well as error-detecting and error-correcting channel coding. They are familiar with the principles of decoding, in particular with modern methods of iterative decoding. They know fundamental coding schemes, their properties and decoding algorithms.
Skills	The students are able to determine the limits of data compression as well as of data transmission through noisy channels and based on those limits to design basic parameters of a transmission scheme. They can estimate the parameters of an error-detecting or error-correcting channel coding scheme for achieving certain performance targets. They are able to compare the properties of basic channel coding and decoding schemes regarding error correction capabilities, decoding delay, decoding complexity and to decide for a suitable method. They are capable of implementing basic coding and decoding schemes in software.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Computational Science and Engineering: Specialisation Kernfächer Ingenieurswissenschaften (2 Kurse): Elective Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory

Course L0436: Information Theory and Coding	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	SoSe
Content	• Fundamentals of information theory ◦ Self information, entropy, mutual information ◦ Source coding theorem, channel coding theorem ◦ Channel capacity of various channels • Fundamental source coding algorithms: ◦ Huffman Code, Lempel Ziv Algorithm • Fundamentals of channel coding ◦ Basic parameters of channel coding and respective bounds ◦ Decoding principles: Maximum-A-Posteriori Decoding, Maximum-Likelihood Decoding, Hard-Decision-Decoding and Soft-Decision-Decoding ◦ Error probability • Block codes • Low Density Parity Check (LDPC) Codes and iterative Ddecoding • Convolutional codes and Viterbi-Decoding • Turbo Codes and iterative decoding • Coded Modulation
Literature	Bossert, M.: Kanalcodierung. Oldenbourg. Friedrichs, B.: Kanalcodierung. Springer. Lin, S., Costello, D.: Error Control Coding. Prentice Hall. Roth, R.: Introduction to Coding Theory. Johnson, S.: Iterative Error Correction. Cambridge. Richardson, T., Urbanke, R.: Modern Coding Theory. Cambridge University Press. Gallager, R. G.: Information theory and reliable communication. Whiley-VCH Cover, T., Thomas, J.: Elements of information theory. Wiley.

Course L0438: Information Theory and Coding	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0837: Simulation of Communication Networks

Courses

Title	Typ	Hrs/wk	CP
Simulation and Modelling of Communication Networks (L0887)	Project-/problem-based Learning	5	6

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	• Knowledge of computer and communication networks • Basic programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain the necessary stochastics, the discrete event simulation technology and modelling of networks for performance evaluation.
Skills	Students are able to apply the method of simulation for performance evaluation to different, also not practiced, problems of communication networks. The students can analyse the obtained results and explain the effects observed in the network. They are able to question their own results.
Personal Competence	
Social Competence	Students are able to acquire expert knowledge in groups, present the results, and discuss solution approaches and results. They are able to work out solutions for new problems in small teams.
Autonomy	Students are able to transfer independently and in discussion with others the acquired method and expert knowledge to new problems. They can identify missing knowledge and acquire this knowledge independently.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory

Course L0887: Simulation and Modelling of Communication Networks

Typ	Project-/problem-based Learning
Hrs/wk	5
CP	6
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	SoSe
Content	In the course necessary basic stochastics and the discrete event simulation are introduced. Also simulation models for communication networks, for example, traffic models, mobility models and radio channel models are presented in the lecture. Students work with a simulation tool, where they can directly try out the acquired skills, algorithms and models. At the end of the course increasingly complex networks and protocols are considered and their performance is determined by simulation.
Literature	• Skript des Instituts für Kommunikationsnetze Further literature is announced at the beginning of the lecture.

Module M1248: Compilers for Embedded Systems

Courses

Title	Typ	Hrs/wk	CP
Compilers for Embedded Systems (L1692)	Lecture	3	4
Compilers for Embedded Systems (L1693)	Project-/problem-based Learning	1	2

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Module "Embedded Systems" C/C++ Programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The relevance of embedded systems increases from year to year. Within such systems, the amount of software to be executed on embedded processors grows continuously due to its lower costs and higher flexibility. Because of the particular application areas of embedded systems, highly optimized and application-specific processors are deployed. Such highly specialized processors impose high demands on compilers which have to generate code of highest quality. After the successful attendance of this course, the students are able • to illustrate the structure and organization of such compilers, • to distinguish and explain intermediate representations of various abstraction levels, and • to assess optimizations and their underlying problems in all compiler phases. The high demands on compilers for embedded systems make effective code optimizations mandatory. The students learn in particular, • which kinds of optimizations are applicable at the source code level, • how the translation from source code to assembly code is performed, • which kinds of optimizations are applicable at the assembly code level, • how register allocation is performed, and • how memory hierarchies can be exploited effectively. Since compilers for embedded systems often have to optimize for multiple objectives (e.g., average- or worst-case execution time, energy dissipation, code size), the students learn to evaluate the influence of optimizations on these different criteria.
Skills	After successful completion of the course, students shall be able to translate high-level program code into machine code. They will be enabled to assess which kind of code optimization should be applied most effectively at which abstraction level (e.g., source or assembly code) within a compiler. While attending the labs, the students will learn to implement a fully functional compiler including optimizations.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1692: Compilers for Embedded Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	• Introduction and Motivation • Compilers for Embedded Systems - Requirements and Dependencies • Internal Structure of Compilers • Pre-Pass Optimizations • HIR Optimizations and Transformations • Code Generation • LIR Optimizations and Transformations • Register Allocation • WCET-Aware Compilation • Outlook
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2 nd Edition, Springer, 2012. • Steven S. Muchnick. Advanced Compiler Design and Implementation. Morgan Kaufmann, 1997. • Andrew W. Appel. Modern compiler implementation in C. Oxford University Press, 1998.

Course L1693: Compilers for Embedded Systems	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0678: Seminar Communications Engineering

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Seminar Communications Engineering (L0448)	Seminar	2	2

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	One or more of the following moduls: • Digital Communications • Mobile Communications • Information theory and coding • Modern Wireless Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students prepare on their own a special topic from communications engineering or digital signal processing.
Skills	The students are able to prepare on their own a special topic from communications engineering or digital signal processing and present it in a seminar talk. They are able to discuss about the topic in a wider context. Furthermore, they are able to contribute to the discussion of other presentations during the seminar.
Personal Competence	
Social Competence	The students are able to discuss within the semnar group.
Autonomy	
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	**Compulsory** Yes, **Bonus** None, **Form** Written elaboration, **Description**
Examination	Presentation
Examination duration and scale	30 minutes presentation, related material, active discussion
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0448: Seminar Communications Engineering

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe/SoSe
Content	changing topics
Literature	je nach Thema

Module M0550: Digital Image Analysis

Courses

Title	Typ	Hrs/wk	CP
Digital Image Analysis (L0126)	Lecture	4	6

Module Responsible	Prof. Rolf-Rainer Grigat
Admission Requirements	None
Recommended Previous Knowledge	System theory of one-dimensional signals (convolution and correlation, sampling theory, interpolation and decimation, Fourier transform, linear time-invariant systems), linear algebra (Eigenvalue decomposition, SVD), basic stochastics and statistics (expectation values, influence of sample size, correlation and covariance, normal distribution and its parameters), basics of Matlab, basics in optics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can • Describe imaging processes • Depict the physics of sensorics • Explain linear and non-linear filtering of signals • Establish interdisciplinary connections in the subject area and arrange them in their context • Interpret effects of the most important classes of imaging sensors and displays using mathematical methods and physical models.
Skills	Students are able to • Use highly sophisticated methods and procedures of the subject area • Identify problems and develop and implement creative solutions. Students can solve simple arithmetical problems relating to the specification and design of image processing and image analysis systems. Students are able to assess different solution approaches in multidimensional decision-making areas. Students can undertake a prototypical analysis of processes in Matlab.
Personal Competence	
Social Competence	k.A.
Autonomy	Students can solve image analysis tasks independently using the relevant literature.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 Minutes, Content of Lecture and materials in StudIP
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory

Course L0126: Digital Image Analysis	
Typ	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Rolf-Rainer Grigat
Language	EN
Cycle	WiSe
Content	• Image representation, definition of images and volume data sets, illumination, radiometry, multispectral imaging, reflectivities, shape from shading • Perception of luminance and color, color spaces and transforms, color matching functions, human visual system, color appearance models • imaging sensors (CMOS, CCD, HDR, X-ray, IR), sensor characterization(EMVA1288), lenses and optics • spatio-temporal sampling (interpolation, decimation, aliasing, leakage, moiré, flicker, apertures) • features (filters, edge detection, morphology, invariance, statistical features, texture) • optical flow (variational methods, quadratic optimization, Euler-Lagrange equations) • segmentation (distance, region growing, cluster analysis, active contours, level sets, energy minimization and graph cuts) • registration (distance and similarity, variational calculus, iterative closest points)
Literature	Bredies/Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 Wedel/Cremers, Stereo Scene Flow for 3D Motion Analysis, Springer 2011 Handels, Medizinische Bildverarbeitung, Vieweg, 2000 Pratt, Digital Image Processing, Wiley, 2001 Jain, Fundamentals of Digital Image Processing, Prentice Hall, 1989

Module M0836: Communication Networks

Courses

Title	Typ	Hrs/wk	CP
Analysis and Structure of Communication Networks (L0897)	Lecture	2	2
Selected Topics of Communication Networks (L0899)	Project-/problem-based Learning	2	2
Communication Networks Excercise (L0898)	Project-/problem-based Learning	1	2

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	• Fundamental stochastics • Basic understanding of computer networks and/or communication technologies is beneficial
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe the principles and structures of communication networks in detail. They can explain the formal description methods of communication networks and their protocols. They are able to explain how current and complex communication networks work and describe the current research in these examples.
Skills	Students are able to evaluate the performance of communication networks using the learned methods. They are able to work out problems themselves and apply the learned methods. They can apply what they have learned autonomously on further and new communication networks.
Personal Competence	
Social Competence	Students are able to define tasks themselves in small teams and solve these problems together using the learned methods. They can present the obtained results. They are able to discuss and critically analyse the solutions.
Autonomy	Students are able to obtain the necessary expert knowledge for understanding the functionality and performance capabilities of new communication networks independently.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Presentation
Examination duration and scale	1.5 hours colloquium with three students, therefore about 30 min per student. Topics of the colloquium are the posters from the previous poster session and the topics of the module.
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory

Course L0897: Analysis and Structure of Communication Networks

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	
Literature	• Skript des Instituts für Kommunikationsnetze • Tannenbaum, Computernetzwerke, Pearson-Studium Further literature is announced at the beginning of the lecture.

Course L0899: Selected Topics of Communication Networks	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	Example networks selected by the students will be researched on in a PBL course by the students in groups and will be presented in a poster session at the end of the term.
Literature	• see lecture

Course L0898: Communication Networks Excercise	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	Part of the content of the lecture Communication Networks are reflected in computing tasks in groups, others are motivated and addressed in the form of a PBL exercise.
Literature	• announced during lecture

Module M0638: Modern Wireless Systems

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Selected Topics of Modern Wireless Systems (L1982)	Project-/problem-based Learning	2	3
Modern Wireless Systems (L0296)	Lecture	2	3

Module Responsible	Dr. Rainer Grünheid
Admission Requirements	None
Recommended Previous Knowledge	• Lecture "Digital Communications" • Lecture "Advanced Concepts of Wireless Communications"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students have an overview of a variety of contemporary wireless systems of different size and complexity. They understand the technical solutions from the perspective of the physical and data link layer. They have developed a system view and are aware of the technical arguments, considering the respective applications and associated constraints. For several examples (e.g., Long Term Evolution, LTE), students are able to explain different concepts in a very deep technical detail.
Skills	Students have developed a system view. They can transfer their knowledge to evaluate other systems, not discussed in the lecture, and to understand the respective technical solutions. Given specific contraints and technical requirements, students are in a position to make proposals for certain design aspects by an appropriate assessment and the consideration of alternatives.
Personal Competence	
Social Competence	Students can jointly elaborate tasks in small groups and present their results in an adequate fashion.
Autonomy	Students are able to extract necessary information from given literature sources and put it into the perspective of the lecture. They can continuously check their level of expertise with the help of accompanying measures (such as online tests, clicker questions, exercise tasks) and, based on that, to steer their learning process accordingly. They can relate their acquired knowledge to topics of other lectures, e.g., "Digital Communications" and "Advanced Topics of Wireless Communications".
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** None · **Form** Subject theoretical and practical work · **Description** PBL-Kurs mit Posterpräsentation
Examination	Oral exam
Examination duration and scale	40 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory

Course L1982: Selected Topics of Modern Wireless Systems

Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Rainer Grünheid
Language	EN
Cycle	WiSe
Content	In this course, selected "hot" topics of modern wireless systems will be covererd. For that purpose, students work in groups to elaborate a given subject. The results will be presented in a poster session towards the end of the semester. Possible topics can include various system concepts and related technical principles, such as: • 5G systems • Millimeter wave communication • Visible light communication • Cooperative Multipoint • Massive MIMO • Massive machine-type communication • Interference cancellation • Non-orthogonal multiple access • Heterogeneous networks • ...
Literature	will be provided, depending on the given topics

Course L0296: Modern Wireless Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Rainer Grünheid
Language	EN
Cycle	WiSe
Content	The lecture gives an overview of contemporary wireless communication concepts and related techniques from a system point of view. For that purpose, different systems, ranging from Wireless Personal to Wide Area Networks, are covered, mainly discussing the physical and data link layer. Systems under consideration include: - ZigBee / IEEE 802.15.4 - Bluetooth - IEEE 802.11 family - Long Term Evolution (LTE) and LTE Advanced - WiMAX A special focus is placed on 4th generation networks; in particular, an in-depth view into the technical principles of the Long Term Evolution (LTE / LTE Advanced) standard is given, with an emphasis on multiple antenna techniques.
Literature	John G. Proakis, Masoud Salehi: Digital Communications. 5th Edition, Irwin/McGraw Hill, 2007 Stefani Sesia, Issam Toufik, Matthew Baker: LTE - The UMTS Long Term Evolution. Second Edition, Wiley, 2011 Jeffrey G. Andrews, Arunabha Ghosh, Rias Muhamed: Fundamentals of WiMAX. Prentice Hall, 2007

Module M0839: Traffic Engineering

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Seminar Traffic Engineering (L0902)	Seminar	2	2
Traffic Engineering (L0900)	Lecture	2	2
Traffic Engineering Exercises (L0901)	Recitation Section (small)	1	2

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	• Fundamentals of communication or computer networks • Stochastics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe methods for planning, optimisation and performance evaluation of communication networks.
Skills	Students are able to solve typical planning and optimisation tasks for communication networks. Furthermore they are able to evaluate the network performance using queuing theory. Students are able to apply independently what they have learned to other and new problems. They can present their results in front of experts and discuss them.
Personal Competence	
Social Competence	
Autonomy	Students are able to acquire the necessary expert knowledge to understand the functionality and performance of new communication networks independently.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory

Course L0902: Seminar Traffic Engineering

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	Selected applications of methods for planning, optimization, and performance evaluation of communication networks, which have been introduced in the traffic engineering lecture are prepared by the students and presented in a seminar.
Literature	• U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Vieweg + Teubner • further literature announced in the lecture

Course L0900: Traffic Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	Network Planning and Optimization • Linear Programming (LP) • Network planning with LP solvers • Planning of communication networks Queueing Theory for Communication Networks • Stochastic processes • Queueing systems • Switches (circuit- and packet switching) • Network of queues
Literature	Literatur: U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer Weitere Literatur wird in der Lehrveranstaltung bekanntgegeben / Literature: U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer further literature announced in the lecture

Course L0901: Traffic Engineering Exercises	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	Accompanying exercise for the traffic engineering course
Literature	Literatur: U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer Weitere Literatur wird in der Lehrveranstaltung bekanntgegeben / Literature: U. Killat, Entwurf und Analyse von Kommunikationsnetzen, Springer further literature announced in the lecture

Module M0738: Digital Audio Signal Processing

Courses

Title	Typ	Hrs/wk	CP
Digital Audio Signal Processing (L0650)	Lecture	3	4
Digital Audio Signal Processing (L0651)	Recitation Section (large)	1	2

Module Responsible	Prof. Udo Zölzer
Admission Requirements	None
Recommended Previous Knowledge	Signals and Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Die Studierenden können die grundlegenden Verfahren und Methoden der digitalen Audiosignalverarbeitung erklären. Sie können die wesentlichen physikalischen Effekte bei der Sprach- und Audiosignalverarbeitung erläutern und in Kategorien einordnen. Sie können einen Überblick der numerischen Methoden und messtechnischen Charakterisierung von Algorithmen zur Audiosignalverarbeitung geben. Sie können die erarbeiteten Algorithmen auf weitere Anwendungen im Bereich der Informationstechnik und Informatik abstrahieren.
Skills	The students will be able to apply methods and techniques from audio signal processing in the fields of mobile and internet communication. They can rely on elementary algorithms of audio signal processing in form of Matlab code and interactive JAVA applets. They can study parameter modifications and evaluate the influence on human perception and technical applications in a variety of applications beyond audio signal processing. Students can perform measurements in time and frequency domain in order to give objective and subjective quality measures with respect to the methods and applications.
Personal Competence	
Social Competence	The students can work in small groups to study special tasks and problems and will be enforced to present their results with adequate methods during the exercise.
Autonomy	The students will be able to retrieve information out of the relevant literature in the field and putt hem into the context of the lecture. They can relate their gathered knowledge and relate them to other lectures (signals and systems, digital communication systems, image and video processing, and pattern recognition). They will be prepared to understand and communicate problems and effects in the field audio signal processing.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory

Course L0650: Digital Audio Signal Processing	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Udo Zölzer
Language	EN
Cycle	WiSe
Content	• Introduction (Studio Technology, Digital Transmission Systems, Storage Media, Audio Components at Home) • Quantization (Signal Quantization, Dither, Noise Shaping, Number Representation) • AD/DA Conversion (Methods, AD Converters, DA Converters, Audio Processing Systems, Digital Signal Processors, Digital Audio Interfaces, Single-Processor Systems, Multiprocessor Systems) • Equalizers (Recursive Audio Filters, Nonrecursive Audio Filters, Multi-Complementary Filter Bank) • Room Simulation (Early Reflections, Subsequent Reverberation, Approximation of Room Impulse Responses) • Dynamic Range Control (Static Curve, Dynamic Behavior, Implementation, Realization Aspects) • Sampling Rate Conversion (Synchronous Conversion, Asynchronous Conversion, Interpolation Methods) • Data Compression (Lossless Data Compression, Lossy Data Compression, Psychoacoustics, ISO-MPEG1 Audio Coding)
Literature	- U. Zölzer, Digitale Audiosignalverarbeitung, 3. Aufl., B.G. Teubner, 2005 . - U. Zölzer, Digitale Audio Signal Processing, 2nd Edition, J. Wiley & Sons, 2005. - U. Zölzer (Ed), Digital Audio Effects, 2nd Edition, J. Wiley & Sons, 2011.

Course L0651: Digital Audio Signal Processing	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Udo Zölzer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0796: Research Project in Information and Communication Systems

Courses			
Title	**Typ**	**Hrs/wk**	**CP**

Module Responsible	Dozenten des SD E
Admission Requirements	None
Recommended Previous Knowledge	Advanced state of knowledge in the electrical engineering master program
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know current research topics oft institutes engaged in their specialization. They can name the fundamental scientific methods used for doing related reserach.
Skills	Students are capable of completing a small, independent sub-project of currently ongoing research projects in the institutes engaged in their specialization. Students can justify and explain their approach for problem solving, they can draw conclusions from their results, and then can find new ways and methods for their work. Students are capable of comparing and assessing alterantive approaches with their own with regard to given criteria.
Personal Competence	
Social Competence	Students are able to discuss their work progress with research assistants of the supervising institute . They are capable of presenting their results in front of a professional audience.
Autonomy	Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research project for themselves. They are able to develop the necessary understanding and problem solving methods.
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Study work
Examination duration and scale	acc. to ASPO
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information and Communication Systems: Compulsory

Module M0677: Digital Signal Processing and Digital Filters

Courses

Title	Typ	Hrs/wk	CP
Digital Signal Processing and Digital Filters (L0446)	Lecture	3	4
Digital Signal Processing and Digital Filters (L0447)	Recitation Section (large)	1	2

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics 1-3 • Signals and Systems • Fundamentals of signal and system theory as well as random processes. • Fundamentals of spectral transforms (Fourier series, Fourier transform, Laplace transform)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know and understand basic algorithms of digital signal processing. They are familiar with the spectral transforms of discrete-time signals and are able to describe and analyse signals and systems in time and image domain. They know basic structures of digital filters and can identify and assess important properties including stability. They are aware of the effects caused by quantization of filter coefficients and signals. They are familiar with the basics of adaptive filters. They can perform traditional and parametric methods of spectrum estimation, also taking a limited observation window into account.
Skills	The students are able to apply methods of digital signal processing to new problems. They can choose and parameterize suitable filter striuctures. In particular, the can design adaptive filters according to the minimum mean squared error (MMSE) criterion and develop an efficient implementation, e.g. based on the LMS or RLS algorithm. Furthermore, the students are able to apply methods of spectrum estimation and to take the effects of a limited observation window into account.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation II. Engineering Science: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0446: Digital Signal Processing and Digital Filters	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe

Content	• Transforms of discrete-time signals:
	  ◦ Discrete-time Fourier Transform (DTFT)
	  ◦ Discrete Fourier-Transform (DFT), Fast Fourier Transform (FFT)
	  ◦ Z-Transform
	• Correspondence of continuous-time and discrete-time signals, sampling, sampling theorem
	• Fast convolution, Overlap-Add-Method, Overlap-Save-Method
	• Fundamental structures and basic types of digital filters
	• Characterization of digital filters using pole-zero plots, important properties of digital filters
	• Quantization effects
	• Design of linear-phase filters
	• Fundamentals of stochastic signal processing and adaptive filters
	  ◦ MMSE criterion
	  ◦ Wiener Filter
	  ◦ LMS- and RLS-algorithm
	• Traditional and parametric methods of spectrum estimation

Literature	K.-D. Kammeyer, K. Kroschel: Digitale Signalverarbeitung. Vieweg Teubner. V. Oppenheim, R. W. Schafer, J. R. Buck: Zeitdiskrete Signalverarbeitung. Pearson StudiumA. V. W. Hess: Digitale Filter. Teubner. Oppenheim, R. W. Schafer: Digital signal processing. Prentice Hall. S. Haykin: Adaptive flter theory. L. B. Jackson: Digital filters and signal processing. Kluwer. T.W. Parks, C.S. Burrus: Digital filter design. Wiley.

Course L0447: Digital Signal Processing and Digital Filters	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization Nanoelectronics and Microsystems Technology

The students of this specialization are introduced into the design of CMOS integrated circuits and the most important manufacturing steps. They gain knowledge and competences regarding the software tools for simulation and of their structure by performing classroom projects. A solid awareness of possible reliability problems and how to prevent them belongs to the acquired competences. Furthermore, the students get competences in the field of microsystem technology and in the usage of software tools for the design of those microsystems. The students acquire the necessary knowledge to develop as well as challenging integrated circuits and microsystems and to combine both to innovative units.

Module M0643: Optoelectronics I - Wave Optics

Courses

Title	Typ	Hrs/wk	CP
Optoelectronics I: Wave Optics (L0359)	Lecture	2	3
Optoelectronics I: Wave Optics (Problem Solving Course) (L0361)	Recitation Section (small)	1	1

Module Responsible	Prof. Manfred Eich
Admission Requirements	None
Recommended Previous Knowledge	Basics in electrodynamics, calculus
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the fundamental mathematical and physical relations of freely propagating optical waves. They can give an overview on wave optical phenomena such as diffraction, reflection and refraction, etc. Students can describe waveoptics based components such as electrooptical modulators in an application oriented way.
Skills	Students can generate models and derive mathematical descriptions in relation to free optical wave propagation. They can derive approximative solutions and judge factors influential on the components' performance.
Personal Competence	
Social Competence	Students can jointly solve subject related problems in groups. They can present their results effectively within the framework of the problem solving course.
Autonomy	Students are capable to extract relevant information from the provided references and to relate this information to the content of the lecture. They can reflect their acquired level of expertise with the help of lecture accompanying measures such as exam typical exam questions. Students are able to connect their knowledge with that acquired from other lectures.
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Credit points	4
Course achievement	None
Examination	Written exam
Examination duration and scale	40 minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory

Course L0359: Optoelectronics I: Wave Optics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	SoSe
Content	• Introduction to optics • Electromagnetic theory of light • Interference • Coherence • Diffraction • Fourier optics • Polarisation and Crystal optics • Matrix formalism • Reflection and transmission • Complex refractive index • Dispersion • Modulation and switching of light
Literature	Bahaa E. A. Saleh, Malvin Carl Teich, Fundamentals of Photonics, Wiley 2007 Hecht, E., Optics, Benjamin Cummings, 2001 Goodman, J.W. Statistical Optics, Wiley, 2000 Lauterborn, W., Kurz, T., Coherent Optics: Fundamentals and Applications, Springer, 2002

Course L0361: Optoelectronics I: Wave Optics (Problem Solving Course)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	SoSe
Content	see lecture Optoelectronics 1 - Wave Optics
Literature	see lecture Optoelectronics 1 - Wave Optics

Module M0747: Microsystem Design

Courses

Title	Typ	Hrs/wk	CP
Microsystem Design (L0683)	Lecture	2	3
Microsystem Design (L0684)	Practical Course	3	3

Module Responsible	Prof. Manfred Kasper
Admission Requirements	None
Recommended Previous Knowledge	Mathematical Calculus, Linear Algebra, Microsystem Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about the most important and most common simulation and design methods used in microsystem design. The scientific background of finite element methods and the basic theory of these methods are known.
Skills	Students are able to apply simulation methods and commercial simulators in a goal oriented approach to complex design tasks. Students know to apply the theory in order achieve estimates of expected accuracy and can judge and verify the correctness of results. Students are able to develop a design approach even if only incomplete information about material data or constraints are available. Student can make use of approximate and reduced order models in a preliminary design stage or a system simulation.
Personal Competence	
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly. Students can develop and explain their solution approach and subdivide the design task to subproblems which are solved separately by group members.
Autonomy	Students are able to acquire particular knowledge using specialized literature and to integrate and associate this knowledge with other fields.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: None; **Form**: Written elaboration; **Description**:
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0683: Microsystem Design	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Manfred Kasper
Language	EN
Cycle	SoSe
Content	Finite difference methods Approximation error Finite element method Order of convergence Error estimation, mesh refinement Makromodeling Reduced order modeling Black-box models System identification Multi-physics systems System simulation Levels of simulation, network simulation Transient problems Non-linear problems Introduction to Comsol Application to thermal, electric, electromagnetic, mechanical and fluidic problems
Literature	M. Kasper: Mikrosystementwurf, Springer (2000) S. Senturia: Microsystem Design, Kluwer (2001)

Course L0684: Microsystem Design	
Typ	Practical Course
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Manfred Kasper
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0935: Microcontroller Circuits: Implementation in Hardware and Software

Courses

Title	Typ	Hrs/wk	CP
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2

Module Responsible	Prof. Siegfried Rump
Admission Requirements	None
Recommended Previous Knowledge	lecture: Computer Architectures
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can describe parts and operation of a common family of microcontrollers. They know details about operations of CPUs, and they can transfer algorithms to machine code.
Skills	The students can design and use electronic circuits (digital with some analogue parts). Furthermore they are able to implement solutions of some tasks by way of assembler programming on these circuits.
Personal Competence	
Social Competence	Groups of two students work on special projects. The students have the skill to separate the project into smaller parts and to present the achieved results in an appropriate short talk.
Autonomy	The student can use, select and estimate suitable sources, which are available from information technology companies. They apply those findings to their projects.
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Written elaboration
Examination duration and scale	15 minutes + disputation
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	ATmega16A 8-bit Microcontroller with 16K Bytes In-System Programmable Flash - DATASHEET, Atmel Corporation 2014 Atmel AVR 8-bit Instruction Set Instruction Set Manual, Atmel Corporation 2016

Module M0761: Semiconductor Technology

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Semiconductor Technology (L0722)	Lecture	4	4
Semiconductor Technology (L0723)	Practical Course	2	2

Module Responsible	Prof. Hoc Khiem Trieu
Admission Requirements	None
Recommended Previous Knowledge	Basics in physics, chemistry, material science and semiconductor devices
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able • to describe and to explain current fabrication techniques for Si and GaAs substrates, • to discuss in details the relevant fabrication processes, process flows and the impact thereof on the fabrication of semiconductor devices and integrated circuits and • to present integrated process flows.
Skills	Students are capable • to analyze the impact of process parameters on the processing results , • to select and to evaluate processes and • to develop process flows for the fabrication of semiconductor devices.
Personal Competence	
Social Competence	Students are able to prepare and perform their lab experiments in team work as well as to present and discuss the results in front of audience.
Autonomy	None
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory

Course L0722: Semiconductor Technology	
Typ	Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Hoc Khiem Trieu
Language	DE/EN
Cycle	SoSe
Content	• Introduction (historical view and trends in microelectronics) • Basics in material science (semiconductor, crystal, Miller indices, crystallographic defects) • Crystal fabrication (crystal pulling for Si and GaAs: impurities, purification, Czochralski , Bridgeman and float zone process) • Wafer fabrication (process flow, specification, SOI) • Fabrication processes • Doping (energy band diagram, doping, doping by alloying, doping by diffusion: transport processes, doping profile, higher order effects and process technology, ion implantation: theory, implantation profile, channeling, implantation damage, annealing and equipment) • Oxidation (silicon dioxide: structure, electrical properties and oxide charges, thermal oxidation: reactions, kinetics, influences on growth rate, process technology and equipment, anodic oxidation, plasma oxidation, thermal oxidation of GaAs) • Deposition techniques (theory: nucleation, film growth and structure zone model, film growth process, reaction kinetics, temperature dependence and equipment; epitaxy: gas phase, liquid phase, molecular beam epitaxy; CVD techniques: APCVD, LPCVD, deposition of metal silicide, PECVD and LECVD; basics of plasma, equipment, PVD techniques: high vacuum evaporation, sputtering) • Structuring techniques (subtractive methods, photolithography: resist properties, printing techniques: contact, proximity and projection printing, resolution limit, practical issues and equipment, additive methods: liftoff technique and electroplating, improving resolution: excimer laser light source, immersion lithography and phase shift lithography, electron beam lithography, X-ray lithography, EUV lithography, ion beam lithography, wet chemical etching: isotropic and anisotropic, corner undercutting, compensation masks and etch stop techniques; dry etching: plasma enhanced etching, backsputtering, ion milling, chemical dry etching, RIE, sidewall passivation) • Process integration (CMOS process, bipolar process) • Assembly and packaging technology (hierarchy of integration, packages, chip-on-board, chip assembly, electrical contact: wire bonding, TAB and flip chip, wafer level package, 3D stacking)
Literature	S.K. Ghandi: VLSI Fabrication principles - Silicon and Gallium Arsenide, John Wiley & Sons S.M. Sze: Semiconductor Devices - Physics and Technology, John Wiley & Sons U. Hilleringmann: Silizium-Halbleitertechnologie, Teubner Verlag H. Beneking: Halbleitertechnologie - Eine Einführung in die Prozeßtechnik von Silizium und III-V-Verbindungen, Teubner Verlag K. Schade: Mikroelektroniktechnologie, Verlag Technik Berlin S. Campbell: The Science and Engineering of Microelectronic Fabrication, Oxford University Press P. van Zant: Microchip Fabrication - A Practical Guide to Semiconductor Processing, McGraw-Hill

Course L0723: Semiconductor Technology	
Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Hoc Khiem Trieu
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0930: Semiconductor Seminar

Courses

Title	Typ	Hrs/wk	CP
Semiconductor Seminar (L0760)	Seminar	2	2

Module Responsible	Prof. Matthias Kuhl
Admission Requirements	None
Recommended Previous Knowledge	Semiconductors
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the most important facts and relationships of a specific topic from the field of semiconductors.
Skills	Students are able to compile a specified topic from the field of semiconductors and to give a clear, structured and comprehensible presentation of the subject. They can comply with a given duration of the presentation. They can write in English a summary including illustrations that contains the most important results, relationships and explanations of the subject.
Personal Competence	
Social Competence	Students are able to adapt their presentation with respect to content, detailedness, and presentation style to the composition and previous knowledge of the audience. They can answer questions from the audience in a curt and precise manner.
Autonomy	Students are able to autonomously carry out a literature research concerning a given topic. They can independently evaluate the material. They can self-reliantly decide which parts of the material should be included in the presentation.
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	15 minutesw presentation + 5-10 minutes discussion + 2 pages written abstract
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0760: Semiconductor Seminar

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl, Prof. Manfred Kasper, Prof. Manfred Eich, Prof. Hoc Khiem Trieu
Language	EN
Cycle	SoSe
Content	Prepare, present, and discuss talks about recent topics from the field of semiconductors. The presentations must be given in English. ***Evaluation Criteria:*** • understanding of subject, discussion, response to questions • structure and logic of presentation (clarity, precision) • coverage of the topic, selection of subjects presented • linguistic presentation (clarity, comprehensibility) • visual presentation (clarity, comprehensibility) • handout (see below) • compliance with timing requirement. ***Handout:*** Before your presentation, it is mandatory to distribute a printed handout (short abstract) of your presentation in English language. This must be no longer than two pages A4, and include the most important results, conclusions, explanations and diagrams.
Literature	Aktuelle Veröffentlichungen zu dem gewählten Thema

Module M0918: Fundamentals of IC Design

Courses

Title	Typ	Hrs/wk	CP
Fundamentals of IC Design (L0766)	Lecture	2	3
Fundamentals of IC Design (L1057)	Practical Course	2	3

Module Responsible	Prof. Matthias Kuhl
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of electrical engineering, electronic devices and circuits
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the basic structure of the circuit simulator SPICE. • Students are able to describe the differences between the MOS transistor models of the circuit simulator SPICE. • Students can discuss the different concept for realization the hardware of electronic circuits. • Students can exemplify the approaches for “Design for Testability”. • Students can specify models for calculation of the reliability of electronic circuits.
Skills	• Students can determine the input parameters for the circuit simulation program SPICE. • Students can select the most appropriate MOS modelling approaches for circuit simulations. • Students can quantify the trade-off of different design styles. • Students can determine the lot sizes and costs for reliability analysis.
Personal Competence	
Social Competence	• Students can compile design studies by themselves or together with partners. • Students are able to select the most efficient design methodology for a given task. • Students are able to define the work packages for design teams.
Autonomy	• Students are able to assess the strengths and weaknesses of their design work in a self-contained manner. • Students can name and bring together all the tools required for total design flow.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	40 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0766: Fundamentals of IC Design	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl
Language	DE/EN
Cycle	SoSe
Content	• Circuit-Simulator SPICE • SPICE-Models for MOS transistors • IC design • Technology of MOS circuits • Standard cell design • Design of gate arrays • Examples for realization of ASICs in the institute of nanoelectronics • Reliability of integrated circuits • Testing of integrated circuits
Literature	R. J. Baker, „CMOS-Circuit Design, Layout, and Simulation“, Wiley & Sons, IEEE Press, 2010 X. Liu, VLSI-Design Methodology Demystified; IEEE, 2009 N. Van Helleputte, J. M. Tomasik, W. Galjan, A. Mora-Sanchez, D. Schroeder, W. H. Krautschneider, R. Puers, A flexible system-on-chip (SoC) for biomedical signal acquisition and processing, Sensors and Actuators A: Physical, vol. 142, p. 361-368, 2008.

Course L1057: Fundamentals of IC Design	
Typ	Practical Course
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0644: Optoelectronics II - Quantum Optics

Courses

Title	Typ	Hrs/wk	CP
Optoelectronics II: Quantum Optics (L0360)	Lecture	2	3
Optoelectronics II: Quantum Optics (Problem Solving Course) (L0362)	Recitation Section (small)	1	1

Module Responsible	Prof. Manfred Eich
Admission Requirements	None
Recommended Previous Knowledge	Basic principles of electrodynamics, optics and quantum mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the fundamental mathematical and physical relations of quantum optical phenomena such as absorption, stimulated and spontanous emission. They can describe material properties as well as technical solutions. They can give an overview on quantum optical components in technical applications.
Skills	Students can generate models and derive mathematical descriptions in relation to quantum optical phenomena and processes. They can derive approximative solutions and judge factors influential on the components' performance.
Personal Competence	
Social Competence	Students can jointly solve subject related problems in groups. They can present their results effectively within the framework of the problem solving course.
Autonomy	Students are capable to extract relevant information from the provided references and to relate this information to the content of the lecture. They can reflect their acquired level of expertise with the help of lecture accompanying measures such as exam typical exam questions. Students are able to connect their knowledge with that acquired from other lectures.
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Credit points	4
Course achievement	None
Examination	Written exam
Examination duration and scale	40 minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory

Course L0360: Optoelectronics II: Quantum Optics

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	WiSe
Content	• Generation of light • Photons • Thermal and nonthermal light • Laser amplifier • Noise • Optical resonators • Spectral properties of laser light • CW-lasers (gas, solid state, semiconductor) • Pulsed lasers
Literature	Bahaa E. A. Saleh, Malvin Carl Teich, Fundamentals of Photonics, Wiley 2007 Demtröder, W., Laser Spectroscopy: Basic Concepts and Instrumentation, Springer, 2002 Kasap, S.O., Optoelectronics and Photonics: Principles and Practices, Prentice Hall, 2001 Yariv, A., Quantum Electronics, Wiley, 1988 Wilson, J., Hawkes, J., Optoelectronics: An Introduction, Prentice Hall, 1997, ISBN: 013103961X Siegman, A.E., Lasers, University Science Books, 1986

Course L0362: Optoelectronics II: Quantum Optics (Problem Solving Course)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Manfred Eich
Language	EN
Cycle	WiSe
Content	see lecture Optoelectronics 1 - Wave Optics
Literature	see lecture Optoelectronics 1 - Wave Optics

Module M0768: Microsystems Technology in Theory and Practice

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Microsystems Technology (L0724)	Lecture	2	4
Microsystems Technology (L0725)	Project-/problem-based Learning	2	2

Module Responsible	Prof. Hoc Khiem Trieu
Admission Requirements	None
Recommended Previous Knowledge	Basics in physics, chemistry, mechanics and semiconductor technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able • to present and to explain current fabrication techniques for microstructures and especially methods for the fabrication of microsensors and microactuators, as well as the integration thereof in more complex systems • to explain in details operation principles of microsensors and microactuators and • to discuss the potential and limitation of microsystems in application.
Skills	Students are capable • to analyze the feasibility of microsystems, • to develop process flows for the fabrication of microstructures and • to apply them.
Personal Competence	
Social Competence	Students are able to prepare and perform their lab experiments in team work as well as to present and discuss the results in front of audience.
Autonomy	None
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: None; **Form**: Subject theoretical and practical work; **Description**: Studierenden führen in Kleingruppen ein Laborpraktikum durch. Jede Gruppe präsentiert und diskutiert die Theorie sowie die Ergebniise ihrer Labortätigkeit. vor dem gesamten Kurs.
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L0725: Microsystems Technology	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0919: Laboratory: Analog and Digital Circuit Design

Courses

Title	Typ	Hrs/wk	CP
Laboratory: Analog Circuit Design (L0692)	Practical Course	2	3
Laboratory: Digital Circuit Design (L0694)	Practical Course	2	3

Module Responsible	Prof. Matthias Kuhl
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of semiconductor devices and circuit design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the structure and philosophy of the software framework for circuit design. • Students can determine all necessary input parameters for circuit simulation. • Students know the basics physics of the analog behavior. • Students are able to explain the functions of the logic gates of their digital design. • Students can explain the algorithms of checking routines. • Students are able to select the appropriate transistor models for fast and accurate simulations.
Skills	• Students can activate and execute all necessary checking routines for verification of proper circuit functionality. • Students are able to run the input desks for definition of their electronic circuits. • Students can define the specifications of the electronic circuits to be designed. • Students can optimize the electronic circuits for low-noise and low-power. • Students can develop analog circuits for mobile medical applications. • Students can define the building blocks of digital systems.
Personal Competence	
Social Competence	• Students are trained to work through complex circuits in teams. • Students are able to share their knowledge for efficient design work. • Students can help each other to understand all the details and options of the design software. • Students are aware of their limitations regarding circuit design, so they do not go ahead, but they involve experts when required. • Students can present their design approaches for easy checking by more experienced experts.
Autonomy	• Students are able to realistically judge the status of their knowledge and to define actions for improvements when necessary. • Students can break down their design work in sub-tasks and can schedule the design work in a realistic way. • Students can handle the complex data structures of their design task and document it in consice but understandable way. • Students are able to judge the amount of work for a major design project.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0692: Laboratory: Analog Circuit Design	
Typ	Practical Course
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl
Language	DE
Cycle	WiSe
Content	• Input desk for circuits • Algorithms for simulation • MOS transistor model • Simulation of analog circuits • Placement and routing • Generation of layouts • Design checking routines • Postlayout simulations
Literature	Handouts to be distributed

Course L0694: Laboratory: Digital Circuit Design	
Typ	Practical Course
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl
Language	DE
Cycle	SoSe
Content	• Definition of specifications • Architecture studies • Digital simulation flow • Philosophy of standard cells • Placement and routing of standard cells • Layout generation • Design checking routines
Literature	Handouts will be distributed

Module M0797: Research Project in Nanoelectronics and Microsystems Technology

Courses			
Title	**Typ**	**Hrs/wk**	**CP**

Module Responsible	Dozenten des SD E
Admission Requirements	None
Recommended Previous Knowledge	Advanced state of knowledge in the electrical engineering master program
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know current research topics oft institutes engaged in their specialization. They can name the fundamental scientific methods used for doing related reserach.
Skills	Students are capable of completing a small, independent sub-project of currently ongoing research projects in the institutes engaged in their specialization. Students can justify and explain their approach for problem solving, they can draw conclusions from their results, and then can find new ways and methods for their work. Students are capable of comparing and assessing alterantive approaches with their own with regard to given criteria.
Personal Competence	
Social Competence	Students are able to discuss their work progress with research assistants of the supervising institute . They are capable of presenting their results in front of a professional audience.
Autonomy	Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research project for themselves. They are able to develop the necessary understanding and problem solving methods.
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Study work
Examination duration and scale	acc. to ASPO
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Compulsory

Module M1048: Electronic Devices and Circuits

Courses

Title	Typ	Hrs/wk	CP
Electronic Devices (L0998)	Lecture	2	3
Circuit Design (L0691)	Lecture	2	3

Module Responsible	Prof. Matthias Kuhl
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of (solid-state) physics and mathematics. Knowledge in fundamentals of electrical engineering and electrical networks.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain basic concepts of electron transport in semiconductor devices (energy bands, generation/recombination, carrier concentrations, drift and diffusion current densities, semiconductor device equations). • Students are able to explain functional principles of pn-diodes, MOS capacitors, and MOSFETs using energy band diagrams. • Students can present and discuss current-voltage relationships and small-signal equivalent circuits of these devices. • Students can explain the physics and current-voltage behavior transistors based on charged carrier flow. • Students are able to explain the basic concepts for static and dynamic logic gates for integrated circuits • Students can exemplify approaches for low power consumption on the device and circuit level • Students can describe the potential and limitations of analytical expression for device and circuit analysis. • Students can explain characterization techniques for MOS devices.
Skills	• Students can qualitatively construct energy band diagrams of the devices for varying applied voltages. • Students are able to qualitatively determine electric field, carrier concentrations, and charge flow from energy band diagrams. • Students can understand scientific publications from the field of semiconductor devices. • Students can calculate the dimensions of MOS devices in dependence of the circuits properties • Students can design complex electronic circuits and anticipate possible problems. • Students know procedure for optimization regarding high performance and low power consumption
Personal Competence	
Social Competence	• Students can team up with other experts in the field to work out innovative solutions. • Students are able to work by their own or in small groups for solving problems and answer scientific questions. • Students have the ability to critically question the value of their contributions to working groups.
Autonomy	• Students are able to assess their knowledge in a realistic manner. • Students are able to define their personal approaches to solve challenging problems
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0998: Electronic Devices	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl
Language	EN
Cycle	WiSe
Content	The basic description of electron transport in semiconductors is introduced. Electronic operating principles of diodes, MOS capacitors, and MOS field-effect transistors are presented. The way to derive mathematical device models from physical principles is described in much detail. These models allow the understanding and simulation of electronic circuits built from the devices.
Literature	Yuan Taur, Tak H. Ning Fundamentals of Modern VLSI Devices Cambridge University Press 1998 ISBN 0-521-55959-6 TU-Library: EKH-738 (Lehrbuchsammlung)

Course L0691: Circuit Design	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl
Language	EN
Cycle	WiSe
Content	• MOS transistor as four terminal device • Performace degradation due to short channel effects • Scaling-down of MOS technology • Digital logic circuits • Basic analog circuits • Operational amplifiers • Bipolar and BiCMOS circuits
Literature	• R. Jacob Baker: CMOS, Circuit Design, Layout and Simulation, IEEE Press, Wiley Interscience, 3rd Edition, 2010 • Neil H.E. Weste and David Money Harris, Integrated Circuit Design, Pearson, 4th International Edition, 2013 • John E. Ayers, Digital Integrated Circuits: Analysis and Design, CRC Press, 2009 • Richard C. Jaeger and Travis N. Blalock: Microelectronic Circuit Design, Mc Graw-Hill, 4rd. Edition, 2010

Module M0781: EMC II: Signal Integrity and Power Supply of Electronic Systems

Courses

Title	Typ	Hrs/wk	CP
EMC II: Signal Integrity and Power Supply of Electronic Systems (L0770)	Lecture	3	4
EMC II: Signal Integrity and Power Supply of Electronic Systems (L0771)	Recitation Section (small)	1	1
EMC II: Signal Integrity and Power Supply of Electronic Systems (L0774)	Practical Course	1	1

Module Responsible	Prof. Christian Schuster
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of electrical engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain the fundamental principles, inter-dependencies, and methods of signal and power integrity of electronic systems. They are able to relate signal and power integrity to the context of interference-free design of such systems, i.e. their electromagnetic compatibility. They are capable of explaining the basic behavior of signals and power supply in typical packages and interconnects. They are able to propose and describe problem solving strategies for signal and power integrity issues. They are capable of giving an overview over measurement and simulation methods for characterization of signal and power integrity in electrical engineering practice.
Skills	Students are able to apply a series of modeling methods for characterization of electromagnetic field behavior in packages and interconnect structure of electronic systems. They are able to determine the most important effects that these models are predicting in terms of signal and power integrity. They can classify these effects and they can quantitatively analyze them. They are capable of deriving problem solving strategies from these predictions and they can adapt them to applications in electrical engineering practice. The can evaluate their problem solving strategies against each other.
Personal Competence	
Social Competence	Students are able to work together on subject related tasks in small groups. They are able to present their results effectively in English (e.g. during CAD exercises).
Autonomy	Students are capable to gather necessary information from the references provided and relate that information to the context of the lecture. They are able to make a connection between their knowledge obtained in this lecture with the content of other lectures (e.g. theory of electromagnetic fields, communications, and semiconductor circuit design). They can communicate problems and solutions in the field of signal integrity and power supply of interconnect and packages in English.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	Compulsory: Yes; Bonus: None; Form: Presentation; Description:
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory

Course L0770: EMC II: Signal Integrity and Power Supply of Electronic Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	- The role of packages and interconnects in electronic systems - Components of packages and interconnects in electronic systems - Main goals and concepts of signal and power integrity of electronic systems - Repeat of relevant concepts from the theory electromagnetic fields - Properties of digital signals and systems - Design and characterization of signal integrity - Design and characterization of power supply - Techniques and devices for measurements in time- and frequency-domain - CAD tools for electrical analysis and design of packages and interconnects - Connection to overall electromagnetic compatibility of electronic systems
Literature	- J. Franz, "EMV: Störungssicherer Aufbau elektronischer Schaltungen", Springer (2012) - R. Tummala, "Fundamentals of Microsystems Packaging", McGraw-Hill (2001) - S. Ramo, J. Whinnery, T. Van Duzer, "Fields and Waves in Communication Electronics", Wiley (1994) - S. Thierauf, "Understanding Signal Integrity", Artech House (2010) - M. Swaminathan, A. Engin, "Power Integrity Modeling and Design for Semiconductors and Systems", Prentice-Hall (2007)

Course L0771: EMC II: Signal Integrity and Power Supply of Electronic Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0774: EMC II: Signal Integrity and Power Supply of Electronic Systems	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	- The role of packages and interconnects in electronic systems - Components of packages and interconnects in electronic systems - Main goals and concepts of signal and power integrity of electronic systems - Repeat of relevant concepts from the theory electromagnetic fields - Properties of digital signals and systems - Design and characterization of signal integrity - Design and characterization of power supply - Techniques and devices for measurements in time- and frequency-domain - CAD tools for electrical analysis and design of packages and interconnects - Connection to overall electromagnetic compatibility of electronic systems
Literature	- J. Franz, "EMV: Störungssicherer Aufbau elektronischer Schaltungen", Springer (2012) - R. Tummala, "Fundamentals of Microsystems Packaging", McGraw-Hill (2001) - S. Ramo, J. Whinnery, T. Van Duzer, "Fields and Waves in Communication Electronics", Wiley (1994) - S. Thierauf, "Understanding Signal Integrity", Artech House (2010) - M. Swaminathan, A. Engin, "Power Integrity Modeling and Design for Semiconductors and Systems", Prentice-Hall (2007)

Specialization Control and Power Systems Engineering

This specialization offers a wide range of topics with respect to various concepts of control and electric power systems, process measurement, robotics, communication networks and digital signal processing.

Students are enabled to analyze, to model and to simulate complex dynamical systems like electric power systems. Moreover, they acquire a profound knowledge about various methods to monitor and control complex systems and to specifically influence their dynamic behavior. In addition, they are able to understand information systems and their recent technologies used in electrical power engineering and develop innovative approaches for smart grids.

As a result, the students will have the skills to entirely analyze, design and optimize all aspects of control and electric power systems. In today's age of increasing digitalization, automation and communication within many branches of industry especially towards a sustainable electrical power supply, this expertise is of outstanding importance for positions in industry and academia.

Module M0692: Approximation and Stability

Courses

Title	Typ	Hrs/wk	CP
Approximation and Stability (L0487)	Lecture	3	4
Approximation and Stability (L0488)	Recitation Section (small)	1	2

Module Responsible	Prof. Marko Lindner
Admission Requirements	None
Recommended Previous Knowledge	• Linear Algebra: systems of linear equations, least squares problems, eigenvalues, singular values • Analysis: sequences, series, differentiation, integration
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • sketch and interrelate basic concepts of functional analysis (Hilbert space, operators), • name and understand concrete approximation methods, • name and explain basic stability theorems, • discuss spectral quantities, conditions numbers and methods of regularisation
Skills	Students are able to • apply basic results from functional analysis, • apply approximation methods, • apply stability theorems, • compute spectral quantities, • apply regularisation methods.
Personal Competence	
Social Competence	Students are able to solve specific problems in groups and to present their results appropriately (e.g. as a seminar presentation).
Autonomy	• Students are capable of checking their understanding of complex concepts on their own. They can specify open questions precisely and know where to get help in solving them. • Students have developed sufficient persistence to be able to work for longer periods in a goal-oriented manner on hard problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	Compulsory: Yes; Bonus: None; Form: Presentation; Description:
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation I. Numerics (TUHH): Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0487: Approximation and Stability	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Marko Lindner
Language	DE/EN
Cycle	SoSe
Content	This course is about solving the following basic problems of Linear Algebra, • systems of linear equations, • least squares problems, • eigenvalue problems but now in function spaces (i.e. vector spaces of infinite dimension) by a stable approximation of the problem in a space of finite dimension. **Contents:** • crash course on Hilbert spaces: metric, norm, scalar product, completeness • crash course on operators: boundedness, norm, compactness, projections • uniform vs. strong convergence, approximation methods • applicability and stability of approximation methods, Polski's theorem • Galerkin methods, collocation, spline interpolation, truncation • convolution and Toeplitz operators • crash course on C*-algebras • convergence of condition numbers • convergence of spectral quantities: spectrum, eigen values, singular values, pseudospectra • regularisation methods (truncated SVD, Tichonov)
Literature	• R. Hagen, S. Roch, B. Silbermann: C*-Algebras in Numerical Analysis • H. W. Alt: Lineare Funktionalanalysis • M. Lindner: Infinite matrices and their finite sections

Course L0488: Approximation and Stability	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Marko Lindner
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0838: Linear and Nonlinear System Identifikation

Courses

Title	Typ	Hrs/wk	CP
Linear and Nonlinear System Identification (L0660)	Lecture	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Classical control (frequency response, root locus) • State space methods • Discrete-time systems • Linear algebra, singular value decomposition • Basic knowledge about stochastic processes
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the general framework of the prediction error method and its application to a variety of linear and nonlinear model structures • They can explain how multilayer perceptron networks are used to model nonlinear dynamics • They can explain how an approximate predictive control scheme can be based on neural network models • They can explain the idea of subspace identification and its relation to Kalman realisation theory
Skills	• Students are capable of applying the predicition error method to the experimental identification of linear and nonlinear models for dynamic systems • They are capable of implementing a nonlinear predictive control scheme based on a neural network model • They are capable of applying subspace algorithms to the experimental identification of linear models for dynamic systems • They can do the above using standard software tools (including the Matlab System Identification Toolbox)
Personal Competence	
Social Competence	Students can work in mixed groups on specific problems to arrive at joint solutions.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0660: Linear and Nonlinear System Identification	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	• Prediction error method • Linear and nonlinear model structures • Nonlinear model structure based on multilayer perceptron network • Approximate predictive control based on multilayer perceptron network model • Subspace identification
Literature	• Lennart Ljung, System Identification - Theory for the User, Prentice Hall 1999 • M. Norgaard, O. Ravn, N.K. Poulsen and L.K. Hansen, Neural Networks for Modeling and Control of Dynamic Systems, Springer Verlag, London 2003 • T. Kailath, A.H. Sayed and B. Hassibi, Linear Estimation, Prentice Hall 2000

Module M0935: Microcontroller Circuits: Implementation in Hardware and Software

Courses

Title	Typ	Hrs/wk	CP
Microcontroller Circuits: Implementation in Hardware and Software (L0087)	Seminar	2	2

Module Responsible	Prof. Siegfried Rump
Admission Requirements	None
Recommended Previous Knowledge	lecture: Computer Architectures
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can describe parts and operation of a common family of microcontrollers. They know details about operations of CPUs, and they can transfer algorithms to machine code.
Skills	The students can design and use electronic circuits (digital with some analogue parts). Furthermore they are able to implement solutions of some tasks by way of assembler programming on these circuits.
Personal Competence	
Social Competence	Groups of two students work on special projects. The students have the skill to separate the project into smaller parts and to present the achieved results in an appropriate short talk.
Autonomy	The student can use, select and estimate suitable sources, which are available from information technology companies. They apply those findings to their projects.
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Written elaboration
Examination duration and scale	15 minutes + disputation
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory

Course L0087: Microcontroller Circuits: Implementation in Hardware and Software

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Siegfried Rump
Language	DE
Cycle	WiSe/SoSe
Content	
Literature	ATmega16A 8-bit Microcontroller with 16K Bytes In-System Programmable Flash - DATASHEET, Atmel Corporation 2014 Atmel AVR 8-bit Instruction Set Instruction Set Manual, Atmel Corporation 2016

Module M0714: Numerical Treatment of Ordinary Differential Equations

Courses

Title	Typ	Hrs/wk	CP
Numerical Treatment of Ordinary Differential Equations (L0576)	Lecture	2	3
Numerical Treatment of Ordinary Differential Equations (L0582)	Recitation Section (small)	2	3

Module Responsible	Prof. Sabine Le Borne
Admission Requirements	None
Recommended Previous Knowledge	• Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis & Lineare Algebra I + II sowie Analysis III für Technomathematiker • Basic MATLAB knowledge
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • list numerical methods for the solution of ordinary differential equations and explain their core ideas, • repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem), • explain aspects regarding the practical execution of a method. • select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results
Skills	Students are able to • implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations, • to justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm, • for a given problem, develop a suitable solution approach, if necessary by the composition of several algorithms, to execute this approach and to critically evaluate the results.
Personal Competence	
Social Competence	Students are able to • work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms.
Autonomy	Students are capable • to assess whether the supporting theoretical and practical excercises are better solved individually or in a team, • to assess their individual progress and, if necessary, to ask questions and seek help.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Electrical Engineering: Specialisation Modeling and Simulation: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Scientific Computing: Elective Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation l. Numerics (TUHH): Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0576: Numerical Treatment of Ordinary Differential Equations	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne, Dr. Christian Seifert, Dr. Patricio Farrell
Language	DE/EN
Cycle	SoSe
Content	Numerical methods for Initial Value Problems • single step methods • multistep methods • stiff problems • differential algebraic equations (DAE) of index 1 Numerical methods for Boundary Value Problems • multiple shooting method • difference methods • variational methods
Literature	• E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems • E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems

Course L0582: Numerical Treatment of Ordinary Differential Equations	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sabine Le Borne, Dr. Patricio Farrell
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0840: Optimal and Robust Control

Courses

Title	Typ	Hrs/wk	CP
Optimal and Robust Control (L0658)	Lecture	2	3
Optimal and Robust Control (L0659)	Recitation Section (small)	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Classical control (frequency response, root locus) • State space methods • Linear algebra, singular value decomposition
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the significance of the matrix Riccati equation for the solution of LQ problems. • They can explain the duality between optimal state feedback and optimal state estimation. • They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints. • They can explain how an LQG design problem can be formulated as special case of an H2 design problem. • They can explain how model uncertainty can be represented in a way that lends itself to robust controller design • They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant. • They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities.
Skills	• Students are capable of designing and tuning LQG controllers for multivariable plant models. • They are capable of representing a H2 or H-infinity design problem in the form of a generalized plant, and of using standard software tools for solving it. • They are capable of translating time and frequency domain specifications for control loops into constraints on closed-loop sensitivity functions, and of carrying out a mixed-sensitivity design. • They are capable of constructing an LFT uncertainty model for an uncertain system, and of designing a mixed-objective robust controller. • They are capable of formulating analysis and synthesis conditions as linear matrix inequalities (LMI), and of using standard LMI-solvers for solving them. • They can carry out all of the above using standard software tools (Matlab robust control toolbox).
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0658: Optimal and Robust Control	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	• Optimal regulator problem with finite time horizon, Riccati differential equation • Time-varying and steady state solutions, algebraic Riccati equation, Hamiltonian system • Kalman's identity, phase margin of LQR controllers, spectral factorization • Optimal state estimation, Kalman filter, LQG control • Generalized plant, review of LQG control • Signal and system norms, computing H2 and H∞ norms • Singular value plots, input and output directions • Mixed sensitivity design, H∞ loop shaping, choice of weighting filters • Case study: design example flight control • Linear matrix inequalities, design specifications as LMI constraints (H2, H∞ and pole region) • Controller synthesis by solving LMI problems, multi-objective design • Robust control of uncertain systems, small gain theorem, representation of parameter uncertainty
Literature	• Werner, H., Lecture Notes: "Optimale und Robuste Regelung" • Boyd, S., L. El Ghaoui, E. Feron and V. Balakrishnan "Linear Matrix Inequalities in Systems and Control", SIAM, Philadelphia, PA, 1994 • Skogestad, S. and I. Postlewhaite "Multivariable Feedback Control", John Wiley, Chichester, England, 1996 • Strang, G. "Linear Algebra and its Applications", Harcourt Brace Jovanovic, Orlando, FA, 1988 • Zhou, K. and J. Doyle "Essentials of Robust Control", Prentice Hall International, Upper Saddle River, NJ, 1998

Course L0659: Optimal and Robust Control	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1236: Electrical Power Systems III

Courses

Title	Typ	Hrs/wk	CP
Electrical Power Systems III (L1683)	Lecture	2	3
Electrical Power Systems III (L1684)	Recitation Section (large)	1	1

Module Responsible	Prof. Christian Becker
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of Electrical Engineering, Introduction to Control Systems, Mathematics I, II, III Electrical Power Systems I, II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain in detail and critically evaluate methods for modelling, control and stability analyses of electric power systems.
Skills	With completion of this module the students are able to calculate and analyze the dynamic bahaviour and stability of real electric power systems using appropriate models. They are furthermore able to design voltage and load frequency controllers.
Personal Competence	
Social Competence	The students can participate in specialized and interdisciplinary discussions, advance ideas and represent their own work results in front of others.
Autonomy	Students can independently tap knowledge of the emphasis of the lectures and apply it within further research activities.
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Credit points	4
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 - 60 Minuten
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory

Course L1683: Electrical Power Systems III

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Becker
Language	DE
Cycle	WiSe/SoSe

Content	• modelling of electric power system for dynamics and stability
	• small-signal angle stability
	  ◦ single-machine infinite-bus problem
	  ◦ multi-machine problem
	• transient angle stability
	  ◦ direct-quadrature-zero transformation
	  ◦ equal-area criterion
	  ◦ Ljapunov stability analysis
	  ◦ multi-machine problem
	• dynamical simulation
	  ◦ basics
	  ◦ numerical integration
	• frequency control
	  ◦ island systems
	  ◦ load-frequency control
	  ◦ grid control structures, energy exchange
	• voltage control
	• voltage stability
	• power system dynamics and control with FACTS and HVDC

Literature	E. Handschin: Elektrische Energieübertragungssysteme, Hüthig Verlag P. Kundur: Power System Stability and Control, McGraw-Hill, 1994

Course L1684: Electrical Power Systems III	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Christian Becker
Language	DE
Cycle	WiSe/SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0835: Humanoid Robotics

Courses

Title	Typ	Hrs/wk	CP
Humanoid Robotics (L0663)	Seminar	2	2

Module Responsible	Patrick Göttsch
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to control systems • Control theory and design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain humanoid robots. • Students learn to apply basic control concepts for different tasks in humanoid robotics.
Skills	• Students acquire knowledge about selected aspects of humanoid robotics, based on specified literature • Students generalize developed results and present them to the participants • Students practice to prepare and give a presentation
Personal Competence	
Social Competence	• Students are capable of developing solutions in interdisciplinary teams and present them • They are able to provide appropriate feedback and handle constructive criticism of their own results
Autonomy	• Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the best solution • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students, such that a scientific discussion develops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0663: Humanoid Robotics

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Patrick Göttsch
Language	DE
Cycle	SoSe
Content	• Grundlagen der Regelungstechnik • Control systems theory and design
Literature	- B. Siciliano, O. Khatib. "Handbook of Robotics. Part A: Robotics Foundations", Springer (2008).

Module M0932: Process Measurement Engineering

Courses

Title	Typ	Hrs/wk	CP
Process Measurement Engineering (L1077)	Lecture	2	3
Process Measurement Engineering (L1083)	Recitation Section (large)	1	1

Module Responsible	Prof. Roland Harig
Admission Requirements	None
Recommended Previous Knowledge	Fundamental principles of electrical engineering and measurement technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an understanding of complex, state-of-the-art process measurement equipment. They can relate devices and procedures to a variety of commonly used measurement and communications technology.
Skills	The students are capable of modeling and evaluating complex systems of sensing devices as well as associated communications systems. An emphasis is placed on a system-oriented understanding of the measurement equipment.
Personal Competence	
Social Competence	Students can communicate the discussed technologies using the English language.
Autonomy	Students are capable of gathering necessary information from provided references and relate this information to the lecture. They are able to continually reflect their knowledge by means of activities that accompany the lecture. Based on respective feedback, students are expected to adjust their individual learning process. They are able to draw connections between their knowledge obtained in this lecture and the content of other lectures (e.g. Fundamentals of Electrical Engineering, Analysis, Stochastic Processes, Communication Systems).
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Credit points	4
Course achievement	None
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory

Course L1077: Process Measurement Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	• Process measurement engineering in the context of process control engineering ◦ Challenges of process measurement engineering ◦ Instrumentation of processes ◦ Classification of pickups • Systems theory in process measurement engineering ◦ Generic linear description of pickups ◦ Mathematical description of two-port systems ◦ Fourier and Laplace transformation • Correlational measurement ◦ Wide band signals ◦ Auto- and cross-correlation function and their applications ◦ Fault-free operation of correlational methods • Transmission of analog and digital measurement signals ◦ Modulation process (amplitude and frequency modulation) ◦ Multiplexing ◦ Analog to digital converter
Literature	- Färber: „Prozeßrechentechnik“, Springer-Verlag 1994 - Kiencke, Kronmüller: „Meßtechnik“, Springer Verlag Berlin Heidelberg, 1995 - A. Ambardar: „Analog and Digital Signal Processing“ (1), PWS Publishing Company, 1995, NTC 339 - A. Papoulis: „Signal Analysis“ (1), McGraw-Hill, 1987, NTC 312 (LB) - M. Schwartz: „Information Transmission, Modulation and Noise“ (3,4), McGraw-Hill, 1980, 2402095 - S. Haykin: „Communication Systems“ (1,3), Wiley&Sons, 1983, 2419072 - H. Sheingold: „Analog-Digital Conversion Handbook“ (5), Prentice-Hall, 1986, 2440072 - J. Fraden: „AIP Handbook of Modern Sensors“ (5,6), American Institute of Physics, 1993, MTB 346

Course L1083: Process Measurement Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Roland Harig
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0939: Control Lab A

Courses

Title	Typ	Hrs/wk	CP
Control Lab I (L1093)	Practical Course	1	1
Control Lab II (L1291)	Practical Course	1	1
Control Lab III (L1665)	Practical Course	1	1
Control Lab IV (L1666)	Practical Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Credit points	4
Course achievement	None
Examination	Written elaboration
Examination duration and scale	1
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L1093: Control Lab I

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1291: Control Lab II	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1665: Control Lab III	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1666: Control Lab IV	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M0845: Feedback Control in Medical Technology

Courses

Title	Typ	Hrs/wk	CP
Feedback Control in Medical Technology (L0664)	Lecture	2	3

Module Responsible	Johannes Kreuzer
Admission Requirements	None
Recommended Previous Knowledge	Basics in Control, Basics in Physiology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The lecture will introduce into the fascinating area of medical technology with the engineering point of view. Fundamentals in human physiology will be similarly introduced like knowledge in control theory. Internal control loops of the human body will be discussed in the same way like the design of external closed loop system fo example in for anesthesia control. The handling of PID controllers and modern controller like predictive controller or fuzzy controller or neural networks will be illustrated. The operation of simple equivalent circuits will be discussed.
Skills	Application of modeling, identification, control technology in the field of medical technology.
Personal Competence	
Social Competence	Students can develop solutions to specific problems in small groups and present their results (e.g. during project week)
Autonomy	Students are able to find necessary literature and to set it into the context of the lecture. They are able to continuously evaluate their knowledge and to take control of their learning process. They can combine knowledge from different courses to form a consistent whole.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Oral exam
Examination duration and scale	20 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory

Course L0664: Feedback Control in Medical Technology

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner, Johannes Kreuzer, Christian Neuhaus
Language	DE
Cycle	SoSe
Content	Taking an engineering point of view, the lecture is structured as follows. • Introduction to the topic with selected examples • Physiology - introduction and overview • Regeneration of functions of the cardiovascular system • Regeneration of the respiratory functions • Closed loop control in anesthesia • regeneration of kidney and liver functions • regeneration of motorize function/ rehabilitation engineering • navigation systems and robotic in medicine The lecture will use knowledge from modeling, simulation and controller design and MATLAB and SIMULINK will be used.
Literature	Silbernagel/Depopoulos: Taschenatlas der Physiologie, Thieme Verlag Stuttgart Werner: Kooperative und autonome Systeme der Medizintechnik, Oldenburg Verlag M.C.K.Khoo:“Physiological Control System“, IEEE Press, 2000

Module M0677: Digital Signal Processing and Digital Filters

Courses

Title	Typ	Hrs/wk	CP
Digital Signal Processing and Digital Filters (L0446)	Lecture	3	4
Digital Signal Processing and Digital Filters (L0447)	Recitation Section (large)	1	2

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics 1-3 • Signals and Systems • Fundamentals of signal and system theory as well as random processes. • Fundamentals of spectral transforms (Fourier series, Fourier transform, Laplace transform)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know and understand basic algorithms of digital signal processing. They are familiar with the spectral transforms of discrete-time signals and are able to describe and analyse signals and systems in time and image domain. They know basic structures of digital filters and can identify and assess important properties including stability. They are aware of the effects caused by quantization of filter coefficients and signals. They are familiar with the basics of adaptive filters. They can perform traditional and parametric methods of spectrum estimation, also taking a limited observation window into account.
Skills	The students are able to apply methods of digital signal processing to new problems. They can choose and parameterize suitable filter striuctures. In particular, the can design adaptive filters according to the minimum mean squared error (MMSE) criterion and develop an efficient implementation, e.g. based on the LMS or RLS algorithm. Furthermore, the students are able to apply methods of spectrum estimation and to take the effects of a limited observation window into account.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Computational Science and Engineering: Specialisation II. Engineering Science: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0446: Digital Signal Processing and Digital Filters	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe

Content	• Transforms of discrete-time signals:
	  ◦ Discrete-time Fourier Transform (DTFT)
	  ◦ Discrete Fourier-Transform (DFT), Fast Fourier Transform (FFT)
	  ◦ Z-Transform
	• Correspondence of continuous-time and discrete-time signals, sampling, sampling theorem
	• Fast convolution, Overlap-Add-Method, Overlap-Save-Method
	• Fundamental structures and basic types of digital filters
	• Characterization of digital filters using pole-zero plots, important properties of digital filters
	• Quantization effects
	• Design of linear-phase filters
	• Fundamentals of stochastic signal processing and adaptive filters
	  ◦ MMSE criterion
	  ◦ Wiener Filter
	  ◦ LMS- and RLS-algorithm
	• Traditional and parametric methods of spectrum estimation

Literature	K.-D. Kammeyer, K. Kroschel: Digitale Signalverarbeitung. Vieweg Teubner. V. Oppenheim, R. W. Schafer, J. R. Buck: Zeitdiskrete Signalverarbeitung. Pearson StudiumA. V. W. Hess: Digitale Filter. Teubner. Oppenheim, R. W. Schafer: Digital signal processing. Prentice Hall. S. Haykin: Adaptive flter theory. L. B. Jackson: Digital filters and signal processing. Kluwer. T.W. Parks, C.S. Burrus: Digital filter design. Wiley.

Course L0447: Digital Signal Processing and Digital Filters	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0836: Communication Networks

Courses

Title	Typ	Hrs/wk	CP
Analysis and Structure of Communication Networks (L0897)	Lecture	2	2
Selected Topics of Communication Networks (L0899)	Project-/problem-based Learning	2	2
Communication Networks Excercise (L0898)	Project-/problem-based Learning	1	2

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	• Fundamental stochastics • Basic understanding of computer networks and/or communication technologies is beneficial
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe the principles and structures of communication networks in detail. They can explain the formal description methods of communication networks and their protocols. They are able to explain how current and complex communication networks work and describe the current research in these examples.
Skills	Students are able to evaluate the performance of communication networks using the learned methods. They are able to work out problems themselves and apply the learned methods. They can apply what they have learned autonomously on further and new communication networks.
Personal Competence	
Social Competence	Students are able to define tasks themselves in small teams and solve these problems together using the learned methods. They can present the obtained results. They are able to discuss and critically analyse the solutions.
Autonomy	Students are able to obtain the necessary expert knowledge for understanding the functionality and performance capabilities of new communication networks independently.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Presentation
Examination duration and scale	1.5 hours colloquium with three students, therefore about 30 min per student. Topics of the colloquium are the posters from the previous poster session and the topics of the module.
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory

Course L0897: Analysis and Structure of Communication Networks

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	
Literature	• Skript des Instituts für Kommunikationsnetze • Tannenbaum, Computernetzwerke, Pearson-Studium Further literature is announced at the beginning of the lecture.

Course L0899: Selected Topics of Communication Networks	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	Example networks selected by the students will be researched on in a PBL course by the students in groups and will be presented in a poster session at the end of the term.
Literature	• see lecture

Course L0898: Communication Networks Excercise	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	Part of the content of the lecture Communication Networks are reflected in computing tasks in groups, others are motivated and addressed in the form of a PBL exercise.
Literature	• announced during lecture

Module M1229: Control Lab B

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Control Lab V (L1667)	Practical Course	1	1
Control Lab VI (L1668)	Practical Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Written elaboration
Examination duration and scale	1
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory

Course L1667: Control Lab V

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1668: Control Lab VI

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M1395: Real-Time Systems

Courses

Title	Typ	Hrs/wk	CP
Real-Time Systems (L1974)	Lecture	3	4
Real-Time Systems (L1975)	Recitation Section (small)	1	2

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Computer Engineering, Basic knowledge in embedded systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Real-Time applications are an important class of embedded systems such as driver assistance systems in modern automobiles, medical devices, process plants and aircrafts. Their main feature is that they are required to complete work and deliver services on a timely basis. This course aims at introducing fundamental theories and concepts about real-time systems. As an introduction, the lecture describes several classes of real-time applications (e.g. digital controllers, signal processing, real-time databases and multimedia). It introduces the main characteristics of real-time systems and explains the relationship between timing requirements and functional requirements. Next, this is followed by a reference model used to characterize the main features of real-time applications. Several scheduling approaches (e.g clock-driven and priority-driven) and timing analysis techniques used for the verification and validation of the timing properties of real-time systems are introduced and discussed. The last part of the course will focus on the timing behavior of communications networks taking into account properties such as the end-to-end latency and the delay jitter, and on shared resources access control and synchronization in multiprocessor/multicore architectures.
Skills	Students have solid notions about the basic properties of common real-time systems and the methods used to analyze them. Students are able to characterize and model the timing features of a real-time system. They use schedulability analysis techniques to compute the response time of systems and check if this meets the timing requirements (I.e deadline) of the system.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory

Course L1974: Real-Time Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Ph.D Selma Saidi
Language	EN
Cycle	WiSe
Content	• **Introduction to Real-Time Embedded Systems** • **Characterization of Real-Time Systems** • **Approaches to Real- Time Scheduling** • **Timing Analysis** • **Real-Time Communication** • **Multiprocessor/Multicore Scheduling and Synchronization** • **An example of an Automotive Real Time Systems**
Literature	Book reference: Jane W. S. Liu Real-Time Systems Prentice Hall 2000

Course L1975: Real-Time Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Ph.D Selma Saidi
Language	EN
Cycle	WiSe
Content	
Literature	

Module M1306: Control Lab C

Courses

Title	Typ	Hrs/wk	CP
Control Lab IX (L1836)	Practical Course	1	1
Control Lab VII (L1834)	Practical Course	1	1
Control Lab VIII (L1835)	Practical Course	1	1

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• State space methods • LQG control • H2 and H-infinity optimal control • uncertain plant models and robust control • LPV control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the difference between validation of a control lop in simulation and experimental validation
Skills	• Students are capable of applying basic system identification tools (Matlab System Identification Toolbox) to identify a dynamic model that can be used for controller synthesis • They are capable of using standard software tools (Matlab Control Toolbox) for the design and implementation of LQG controllers • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the mixed-sensitivity design and the implementation of H-infinity optimal controllers • They are capable of representing model uncertainty, and of designing and implementing a robust controller • They are capable of using standard software tools (Matlab Robust Control Toolbox) for the design and the implementation of LPV gain-scheduled controllers
Personal Competence	
Social Competence	• Students can work in teams to conduct experiments and document the results
Autonomy	• Students can independently carry out simulation studies to design and validate control loops
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Credit points	3
Course achievement	None
Examination	Written elaboration
Examination duration and scale	1
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L1836: Control Lab IX

Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1834: Control Lab VII	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Course L1835: Control Lab VIII	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Herbert Werner, Patrick Göttsch, Adwait Datar
Language	EN
Cycle	WiSe/SoSe
Content	One of the offered experiments in control theory.
Literature	Experiment Guides

Module M0794: Research Project in Control and Power Systems

Courses			
Title	**Typ**	**Hrs/wk**	**CP**

Module Responsible	Dozenten des SD E
Admission Requirements	None
Recommended Previous Knowledge	Advanced state of knowledge in the electrical engineering master program
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know current research topics oft institutes engaged in their specialization. They can name the fundamental scientific methods used for doing related reserach.
Skills	Students are capable of completing a small, independent sub-project of currently ongoing research projects in the institutes engaged in their specialization. Students can justify and explain their approach for problem solving, they can draw conclusions from their results, and then can find new ways and methods for their work. Students are capable of comparing and assessing alterantive approaches with their own with regard to given criteria.
Personal Competence	
Social Competence	Students are able to discuss their work progress with research assistants of the supervising institute . They are capable of presenting their results in front of a professional audience.
Autonomy	Based on their competences gained so far students are capable of defining meaningful tasks within ongoing research project for themselves. They are able to develop the necessary understanding and problem solving methods.
Workload in Hours	Independent Study Time 180, Study Time in Lecture 0
Credit points	6
Course achievement	None
Examination	Study work
Examination duration and scale	acc. to ASPO
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Compulsory

Module M1305: Seminar Advanced Topics in Control

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Control (L1803)	Seminar	2	2

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to control systems • Control theory and design • optimal and robust control
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain modern control. • Students learn to apply basic control concepts for different tasks
Skills	• Students acquire knowledge about selected aspects of modern control, based on specified literature • Students generalize developed results and present them to the participants • Students practice to prepare and give a presentation
Personal Competence	
Social Competence	• Students are capable of developing solutions and present them • They are able to provide appropriate feedback and handle constructive criticism of their own results
Autonomy	• Students evaluate advantages and drawbacks of different forms of presentation for specific tasks and select the best solution • Students familiarize themselves with a scientific field, are able of introduce it and follow presentations of other students, such that a scientific discussion develops
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory

Course L1803: Advanced Topics in Control

Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe/SoSe
Content	• Seminar on selected topics in modern control
Literature	• To be specified

Module M0666: Seminar on Electromagnetic Compatibility and Electrical Power Systems

Courses

Title	Typ	Hrs/wk	CP
Seminar on Electromagnetic Compatibility and Electrical Power Systems (L0409)	Seminar	2	2

Module Responsible	Prof. Christian Schuster
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of electrical engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know current research topics in the fields of electromagnetic compatibility, theory of electromagnetic fields, and electrical power systems. They are able to use professional language in discussions. They are able to explain research topics.
Skills	Students are able to gain knowledge about a new field by themselves. In order to do that they make use of their existing knowledge and try to connect it with the topics of the new field. They close their knowledge gaps by discussing with research assistants and by their own literature and internet search. They are capable of summarizing and presenting scientific publications.
Personal Competence	
Social Competence	In cooperation with research assistants students are able to familiarize themselves with and discuss with others current research topics. They are capable of drafting, presenting, and explaining summaries of these topics in English in front of a professional audience.
Autonomy	Students are capable of gathering information from subject related, professional publications and relate that information to the context of the seminar. They are able to find on their own new sources in the Internet. They are able to make a connection with the subject of their chosen specialization.
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Credit points	2
Course achievement	None
Examination	Presentation
Examination duration and scale	20-30 minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory

Course L0409: Seminar on Electromagnetic Compatibility and Electrical Power Systems	
Typ	Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christian Schuster, Prof. Frank Gronwald, Prof. Christian Becker
Language	EN
Cycle	WiSe/SoSe
Content	Current research topics in the fields electromagnetic compatibility, theory of electromagnetic fields, and electrical power systems
Literature	Aktuelle Literatur zu Forschungsthemen aus der elektromagnetischen Verträglichkeit, der theoretischen Elektrotechnik und der elektrischen Energiesystemtechnik / Current literature with regard to research topics in the fields of electromagnetic compatibility, theory of electromagnetic fields, and and electrical power systems

Module M0832: Advanced Topics in Control

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Control (L0661)	Lecture	2	3
Advanced Topics in Control (L0662)	Recitation Section (small)	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	H-infinity optimal control, mixed-sensitivity design, linear matrix inequalities
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the advantages and shortcomings of the classical gain scheduling approach • They can explain the representation of nonlinear systems in the form of quasi-LPV systems • They can explain how stability and performance conditions for LPV systems can be formulated as LMI conditions • They can explain how gridding techniques can be used to solve analysis and synthesis problems for LPV systems • They are familiar with polytopic and LFT representations of LPV systems and some of the basic synthesis techniques associated with each of these model structures • Students can explain how graph theoretic concepts are used to represent the communication topology of multiagent systems • They can explain the convergence properties of first order consensus protocols • They can explain analysis and synthesis conditions for formation control loops involving either LTI or LPV agent models • Students can explain the state space representation of spatially invariant distributed systems that are discretized according to an actuator/sensor array • They can explain (in outline) the extension of the bounded real lemma to such distributed systems and the associated synthesis conditions for distributed controllers
Skills	• Students are capable of constructing LPV models of nonlinear plants and carry out a mixed-sensitivity design of gain-scheduled controllers; they can do this using polytopic, LFT or general LPV models • They are able to use standard software tools (Matlab robust control toolbox) for these tasks • Students are able to design distributed formation controllers for groups of agents with either LTI or LPV dynamics, using Matlab tools provided • Students are able to design distributed controllers for spatially interconnected systems, using the Matlab MD-toolbox
Personal Competence	
Social Competence	Students can work in small groups and arrive at joint results.
Autonomy	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory Computational Science and Engineering: Specialisation Systems Engineering and Robotics: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory

	Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory

Course L0661: Advanced Topics in Control	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	• Linear Parameter-Varying (LPV) Gain Scheduling - Linearizing gain scheduling, hidden coupling - Jacobian linearization vs. quasi-LPV models - Stability and induced L2 norm of LPV systems - Synthesis of LPV controllers based on the two-sided projection lemma - Simplifications: controller synthesis for polytopic and LFT models - Experimental identification of LPV models - Controller synthesis based on input/output models - Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator • Control of Multi-Agent Systems - Communication graphs - Spectral properties of the graph Laplacian - First and second order consensus protocols - Formation control, stability and performance - LPV models for agents subject to nonholonomic constraints - Application: formation control for a team of quadrotor helicopters • Control of Spatially Interconnected Systems - Multidimensional signals, l2 and L2 signal norm - Multidimensional systems in Roesser state space form - Extension of real-bounded lemma to spatially interconnected systems - LMI-based synthesis of distributed controllers - Spatial LPV control of spatially varying systems - Applications: control of temperature profiles, vibration damping for an actuated beam
Literature	• Werner, H., Lecture Notes "Advanced Topics in Control" • Selection of relevant research papers made available as pdf documents via StudIP

Course L0662: Advanced Topics in Control	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0633: Industrial Process Automation

Courses

Title	Typ	Hrs/wk	CP
Industrial Process Automation (L0344)	Lecture	2	3
Industrial Process Automation (L0345)	Recitation Section (small)	2	3

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can evaluate and assess discrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods. The students can relate process automation to methods from robotics and sensor systems as well as to recent topics like 'cyberphysical systems' and 'industry 4.0'.
Skills	The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity, and implementation using PLCs.
Personal Competence	
Social Competence	The students work in teams to solve problems.
Autonomy	The students can reflect their knowledge and document the results of their work.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory**: No; **Bonus**: 10 %; **Form**: Excercises; **Description**:
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0344: Industrial Process Automation	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	- foundations of problem solving and system modeling, discrete event systems - properties of processes, modeling using automata and Petri-nets - design considerations for processes (mutex, deadlock avoidance, liveness) - optimal scheduling for processes - optimal decisions when planning manufacturing systems, decisions under uncertainty - software design and software architectures for automation, PLCs
Literature	J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012 Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010 Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007 Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009 Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009

Course L0345: Industrial Process Automation	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Thesis

Module M-002: Master Thesis

Courses			
Title	**Typ**	**Hrs/wk**	**CP**

Module Responsible	Professoren der TUHH
Admission Requirements	• According to General Regulations §21 (1): At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues. • The students can explain in depth the relevant approaches and terminologies in one or more areas of their subject, describing current developments and taking up a critical position on them. • The students can place a research task in their subject area in its context and describe and critically assess the state of research.
Skills	The students are able: • To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question. • To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/or incompletely defined problems in a solution-oriented way. • To develop new scientific findings in their subject area and subject them to a critical assessment.
Personal Competence	
Social Competence	Students can • Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way. • Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addressees while upholding their own assessments and viewpoints convincingly.
Autonomy	Students are able: • To structure a project of their own in work packages and to work them off accordingly. • To work their way in depth into a largely unknown subject and to access the information required for them to do so. • To apply the techniques of scientific work comprehensively in research of their own.
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	30
Course achievement	None
Examination	Thesis
Examination duration and scale	According to General Regulations
Assignment for the Following Curricula	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy and Environmental Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Global Innovation Management: Thesis: Compulsory Computational Science and Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Materials Science: Thesis: Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Thesis: Compulsory Mechanical Engineering and Management: Thesis: Compulsory

	Mechatronics: Thesis: Compulsory Biomedical Engineering: Thesis: Compulsory Microelectronics and Microsystems: Thesis: Compulsory Product Development, Materials and Production: Thesis: Compulsory Renewable Energies: Thesis: Compulsory Naval Architecture and Ocean Engineering: Thesis: Compulsory Ship and Offshore Technology: Thesis: Compulsory Teilstudiengang Lehramt Metalltechnik: Thesis: Compulsory Theoretical Mechanical Engineering: Thesis: Compulsory Process Engineering: Thesis: Compulsory Water and Environmental Engineering: Thesis: Compulsory