Hamburg University of Technology

Module Manual

Master of Science (M.Sc.)

Microelectronics and Microsystems

Cohort: Winter Term 2019

Updated: 27th April 2019

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Program description

Content

Microelectronics, or better named nanoelectronics, because the minimum structure size of state-of-the-art integrated electronic circuits are in the range of 20 nm and below, is the base of the products that significantly influence the daily life of people almost anywhere on earth. Examples are personal computers and smartphones. Both of them open up new possibilities of communication and give access to almost unlimited sources of information, especially when those devices are connected to the world wide web. Another example are medical diagnostic tools for computer tomography or nuclear resonance tomography or intelligent medical implants as all these systems are based on the high computational performance and high data communication efficiency provided by advanced nanoelectronics.

The fundament for microelectronics and microsystems is semiconductor physics and technology. Thus, the objective of the International Master Program “Microelectronics and Microsystems” is to give the students a profound knowledge on physical level about electronic effects in semiconductor materials, especially silicon, and on the functionality of electronic devices. Furthermore, the students are taught about process technology for fabrication of integrated circuits and microsystems. This will enable the students to understand in depth the function of advanced electronic devices and fabrication processes. They will be able to comprehend in a critical way the problems accompanied with the transition to smaller minimum structure sizes. Thus, the students can conceive which possible solutions may exist or could be developed to overcome the problems of scaling-down the device minimum feature size. This will enable the students to understand the ongoing scaling-down of MOS transistors with its potential but also with its limitations.

Besides the essential role of physical basics the precise knowledge of process dependent manufacturing procedures are of key importance for training of the students in the field of nanoelectronics and microsystems. This will help them to develop during their professional life the ability to generate innovative concepts and bring them to practical applications.

The International Master Program “Microelectronics and Microsystems” qualifies the students for scientific professional work in the fields of electrical engineering and information technology. This professional work may extend from the development, production and application to the quality control of complex systems with highly integrated circuits and microsystems components. Both fields are coming closer and closer together, as a fast rising number of complex applications requires the integration of nanoelectronics and microsystems to one combined system.

In particular, this program enables the students not only to design new complex systems for innovative applications, but also to make them usable for practical applications. This can be realized by teaching the students engineering methods both on a physical and theoretical level and on an application oriented level.

Career prospects

The graduates of the International Master Program “Microelectronics and Microsystems” can find a wide variety of professional options as they have well founded knowledge about technology, design and application of highly integrated systems based on nanoelectronics and microsystems.

Thus, one group of possible employers are large companies with international sites for the production of integrated circuits, but also small or medium-sized companies for microsystems. Many job opportunities also exist in the field of development and design of integrated circuits and of microsystems. Because of the fast decline in prices of high-performance computer system, even small companies can conduct tasks that require many computational efforts such as the design of integrated circuits that, then, are fabricated by specialized companies, so-called silicon foundries. This allows many small companies to participate in the market for integrated circuits, so that they can contribute to a good job market for engineers in nanoelectronics and microsystems.

Learning target

Knowledge

- The students understand the basic physical principles of microelectronic devices and functional block of microsystems. Furthermore, they have solid knowledge regarding fabrication technologies, so that they can explain them in detail.
- They have gained solid knowledge in selected fields based on a broad theoretical and methodical fundament.
- The students possess in-depth knowledge of interdisciplinary relationships.
- They have the required background knowledge in order to position their professional subjects by appropriate means in the scientific and social environment.

Skills

The students are able

- to apply computational methods for quantitative analysis of design parameters and for development of innovative systems for microelectronics and microsystems.

- to solve complex problems and tasks in a self-dependent manner by basic methodical approaches that may be, if necessary, beyond the standard patterns
- to consider technological progress and scientific advancements by taking into account the technical, financial and ecological boundary conditions.

Social Skills

The students are capable of

- working in interdisciplinary teams and organizing their tasks in a process oriented manner to become prepared for conducting research based professional work and for taking management responsibilities.
- to present their results in a written or oral form effectively targeting the audience, on international stage also.

Autonomy

- The students can pervade in an effectively and self-dependently organized way special areas of their professional fields using scientific methods.
- They are able to present their knowledge by appropriate media techniques or to describe it by documents with reasonable lengths.
- The students are able to identify the need for additional information and to develop a strategy for self-dependent enhancement of their knowledge.

Program structure

The curriculum of the International Master Program „Microelectronics and Microsystems“ is structured as follows:

- Core Qualification:

- Main subject: The students choose one main subject out of the following two options:

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The students have to take for their main subjects moduls totaling 18 CPs (1. - 3. semester).

- Master thesis with 30 CP (4. semester)

The sum of required credit points of this Master program is 120 CP.

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.
	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

Autonomy	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 M0913: CMOS Nanoelectronics with Practice

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
CMOS Nanoelectronics (L0764)	Lecture	2	3
CMOS Nanoelectronics (L1063)	Practical Course	2	2
CMOS Nanoelectronics (L1059)	Recitation Section (small)	1	1

Module Responsible	Prof. Matthias Kuhl
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of MOS devices and electronic circuits
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain the functionality of very small MOS transistors and explain the problems occurring due to scaling-down the minimum feature size. • Students are able to explain the basic steps of processing of very small MOS devices. • Students can exemplify the functionality of volatile and non-volatile memories und give their specifications. • Students can describe the limitations of advanced MOS technologies. • Students can explain measurement methods for MOS quality control.
Skills	• Students can quantify the current-voltage-behavior of very small MOS transistors and list possible applications. • Students can describe larger electronic systems by their functional blocks. • Students can name the existing options for the specific applications and select the most appropriate ones.
Personal Competence	
Social Competence	• Students can team up with one or several partners who may have different professional backgrounds • Students are able to work by their own or in small groups for solving problems and answer scientific questions.
Autonomy	• Students are able to assess their knowledge in a realistic manner. • The students are able to draw scenarios for estimation of the impact of advanced mobile electronics on the future lifestyle of the society.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6

Course achievement	**Compulsory Bonus**	**Form**	**Description**
		Subject theoretical and	

	Yes None practical work
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Core qualification: Elective Compulsory

Course L0764: CMOS Nanoelectronics	
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	• Ideal and non-ideal MOS devices • Threshold voltage, Parasitic charges, Work function difference • I-V behavior • Scaling-down rules • Details of very small MOS transistors • Basic CMOS process flow • Memory Technology, SRAM, DRAM, embedded DRAM • Gain memory cells • Non-volatile memories, Flash memory circuits • Methods for Quality Control, C(V)-technique, Charge pumping, Uniform injection • Systems with extremely small CMOS transistors
Literature	• S. Deleonibus, Electronic Device Architectures for the Nano-CMOS Era, Pan Stanford Publishing, 2009. • Y. Taur and T.H. Ning, Fundamentals of Modern VLSI Devices, Cambridge University Press, 2nd edition. • R.F. Pierret, Advanced Semiconductor Fundamentals, Prentice Hall, 2003. • F. Schwierz, H. Wong, J. J. Liou, Nanometer CMOS, Pan Stanford Publishing, 2010. • H.-G. Wagemann und T. Schönauer, Silizium-Planartechnologie, Grundprozesse, Physik und Bauelemente Teubner-Verlag, 2003, ISBN 3519004674

Course L1063: CMOS Nanoelectronics	
Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Matthias Kuhl
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1059: CMOS Nanoelectronics	
Typ	Recitation Section (small)
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	See interlocking course
Literature	See interlocking course

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	
	• 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.

Social Competence	• 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 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 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

Compulsory Bonus	Form	Description
		Studierenden führen in Kleingruppen ein Laborpraktikum

Course achievement	Yes	None	Subject theoretical and practical work	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 M1137: Technical Elective Complementary Course for IMPMM - field ET (according to Subject Specific Regulations)

Courses			
Title	Typ	Hrs/wk	CP

Module Responsible	Prof. Hoc Khiem Trieu
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in electrical enginnering, physics, semiconductor devices and mathematics at Bachelor of Science level
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	As this modul can be chosen from the modul catalogue of the department E, the competence to be acquired is acccording to the chosen subject.
Skills	As this modul can be chosen from the modul catalogue of the department E, the skills to be acquired is acccording to the chosen subject.
Personal Competence	
Social Competence	• Students can team up with one or several partners who may have different professional backgrounds • Students are able to work by their own or in small groups for solving problems and answer scientific questions.
Autonomy	• Students are able to assess their knowledge in a realistic manner. • The students are able to draw scenarios for estimation of the impact of advanced mobile electronics on the future lifestyle of the society.
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Microelectronics and Microsystems: Core qualification: Elective Compulsory

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	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 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** / **Bonus** / **Form** / **Description**: Yes / None / Written elaboration /
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: 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 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 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** / **Bonus** / **Form** / **Description** Yes / None / Written elaboration /
Examination	Presentation
Examination duration and scale	30 minutes presentation, related material, active discussion
Assignment for the Following Curricula	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 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	Written exam
Examination duration and scale	90 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 M1130: Project Work IMPMM

Courses

Title	Typ	Hrs/wk	CP

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	Good knowledge in the design of electronic circuits, microprocessor systems, systems for signal processing and the handling of software packages for simulation of electrical and physical processes.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The student is able to achieve in a specific scientific field special knowledge and she or he can independently acquire in this field the skills necessary for solving these scientific problems.
Skills	The student is able to formulate the scientific problems to be solved and to work out solutions in an independent manner and to realize them.
Personal Competence	
Social Competence	The student can integrate herself or himself into small teams of researchers and she or he can discuss proposals for solutions of scientific problems within the team. She or he is able to present the results in a clear and well structured manner.
Autonomy	The student can perform scientific work in a timely manner and document the results in a detailed and well readable form. She or he is able to anticipate possible problems well in advance and to prepare proposals for their solutions.
Workload in Hours	Independent Study Time 480, Study Time in Lecture 0
Credit points	16
Course achievement	None
Examination	Study work
Examination duration and scale	see FSPO
Assignment for the Following Curricula	Microelectronics and Microsystems: Core qualification: Compulsory

Module M1131: Technical Elective Complementary Course for IMPMM - field TUHH (according to Subject Specific Regulations)

Courses

Title	Typ	Hrs/wk	CP

Module Responsible	Prof. Hoc Khiem Trieu
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in electrical enginnering, physics, semiconductor devices, software and mathematics at Bachelor of Science level.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	As this module can be chosen from the module catalogue of the TUHH, the competence to be acquired is according to the chosen subject.
Skills	As this module can be chosen from the module catalogue of the TUHH, the skills to be acquired is according to the chosen subject.
Personal Competence	
Social Competence	• Students can team up with one or several partners who may have different professional backgrounds • Students are able to work by their own or in small groups for solving problems and answer scientific questions.
Autonomy	
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Microelectronics and Microsystems: Core qualification: Elective Compulsory

Specialization Communication and Signal Processing

Students of the specialization Communication and Signal Processing learn both physical and technical basics of state-of-the-art wired and wireless communication systems and the hardware realization of those systems. They can deepen their knowledge towards core areas such as systems for audio or video signal processing. The students understand the fundamental concepts of those systems and can identify their limitations. Based on this knowledge they are able to determine possible improvements and to implement them.

Students have to choose lectures with a total of 18 credit points from the catalog of this specialization.

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 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 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 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 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 M0552: 3D Computer Vision

Courses

Title	Typ	Hrs/wk	CP
3D Computer Vision (L0129)	Lecture	2	3
3D Computer Vision (L0130)	Recitation Section (small)	2	3

Module Responsible	Prof. Rolf-Rainer Grigat
Admission Requirements	None
Recommended Previous Knowledge	• Knowlege of the modules Digital Image Analysis and Pattern Recognition and Data Compression are used in the practical task • Linear Algebra (including PCA, SVD), nonlinear optimization (Levenberg-Marquardt), basics of stochastics and basics of Matlab are required and cannot be explained in detail during the lecture.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain and describe the field of projective geometry.
Skills	Students are capable of • Implementing an exemplary 3D or volumetric analysis task • Using highly sophisticated methods and procedures of the subject area • Identifying problems and • Developing and implementing creative solution suggestions. With assistance from the teacher students are able to link the contents of the three subject areas (modules) • Digital Image Analysis • Pattern Recognition and Data Compression and • 3D Computer Vision in practical assignments.
Personal Competence	
Social Competence	Students can collaborate in a small team on the practical realization and testing of a system to reconstruct a three-dimensional scene or to evaluate volume data sets.
Autonomy	Students are able to solve simple tasks independently with reference to the contents of the lectures and the exercise sets. Students are able to solve detailed problems independently with the aid of the tutorial's programming task.
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 Computational Science and Engineering: Specialisation Systems Engineering and Robotics: 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 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Numerics and Computer Science: Elective Compulsory

Course L0129: 3D Computer Vision	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Rolf-Rainer Grigat
Language	EN
Cycle	WiSe
Content	• Projective Geometry and Transformations in 2D und 3D in homogeneous coordinates • Projection matrix, calibration • Epipolar Geometry, fundamental and essential matrices, weak calibration, 5 point algorithm • Homographies 2D and 3D • Trifocal Tensor • Correspondence search
Literature	• **Skriptum Grigat/Wenzel** • Hartley, Zisserman: Multiple View Geometry in Computer Vision. Cambridge 2003.

Course L0130: 3D Computer Vision	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Rolf-Rainer Grigat
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

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
	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

Assignment for the Following Curricula	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 Microelectronics Complements: 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 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

Specialization Embedded Systems

Module M0791: Computer Architecture

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Computer Architecture (L0793)	Lecture	2	3
Computer Architecture (L0794)	Project-/problem-based Learning	2	2
Computer Architecture (L1864)	Recitation Section (small)	1	1

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Module "Computer Engineering"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	This module presents advanced concepts from the discipline of computer architecture. In the beginning, a broad overview over various programming models is given, both for general-purpose computers and for special-purpose machines (e.g., signal processors). Next, foundational aspects of the micro-architecture of processors are covered. Here, the focus particularly lies on the so-called pipelining and the methods used for the acceleration of instruction execution used in this context. The students get to know concepts for dynamic scheduling, branch prediction, superscalar execution of machine instructions and for memory hierarchies.
Skills	The students are able to describe the organization of processors. They know the different architectural principles and programming models. The students examine various structures of pipelined processor architectures and are able to explain their concepts and to analyze them w.r.t. criteria like, e.g., performance or energy efficiency. They evaluate different structures of memory hierarchies, know parallel computer architectures and are able to distinguish between instruction- and data-level parallelism.
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 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 15 % / Subject theoretical and practical work /
Examination	Written exam
Examination duration and scale	90 minutes, contents of course and 4 attestations from the PBL "Computer architecture"
	General Engineering Science (German program, 7 semester): Specialisation Computer

Assignment for the Following Curricula	Science: Elective Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory Computational Science and Engineering: Specialisation Computer Science: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L0793: Computer Architecture	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	• Introduction • VHDL Basics • Programming Models • Realization of Elementary Data Types • Dynamic Scheduling • Branch Prediction • Superscalar Machines • Memory Hierarchies The theoretical tutorials amplify the lecture's content by solving and discussing exercise sheets and thus serve as exam preparation. Practical aspects of computer architecture are taught in the FPGA-based PBL on computer architecture whose attendance is mandatory.
Literature	• D. Patterson, J. Hennessy. Rechnerorganisation und -entwurf. Elsevier, 2005. • A. Tanenbaum, J. Goodman. Computerarchitektur. Pearson, 2001.

Course L0794: Computer Architecture	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1864: Computer Architecture	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1400: Design of Dependable Systems

Courses

Title	Typ	Hrs/wk	CP
Designing Dependable Systems (L2000)	Lecture	2	3
Designing Dependable Systems (L2001)	Recitation Section (small)	2	3

Module Responsible	Prof. Görschwin Fey
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge about data structures and algorithms
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	In the following "dependable" summarizes the concepts Reliability, Availability, Maintainability, Safety and Security. Knowledge about approaches for designing dependable systems, e.g., • Structural solutions like modular redundancy • Algorithmic solutions like handling byzantine faults or checkpointing Knowledge about methods for the analysis of dependable systems
Skills	Ability to implement dependable systems using the above approaches. Ability to analyzs the dependability of systems using the above methods for analysis.
Personal Competence	
Social Competence	Students • discuss relevant topics in class and • present their solutions orally.
Autonomy	Using accompanying material students independently learn in-depth relations between concepts explained in the lecture and additional solution strategies.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No, **Bonus** None, **Form** Excercises, **Description** Praktische Übungsaufgaben zur Anwendung der gelernten Ansätze
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L2000: Designing Dependable Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Görschwin Fey
Language	DE/EN
Cycle	SoSe
Content	Description The term dependability comprises various aspects of a system. These are typically: • Reliability • Availability • Maintainability • Safety • Security This makes dependability a core aspect that has to be considered early in system design, no matter whether software, embedded systems or full scale cyber-physical systems are considered. Contents The module introduces the basic concepts for the design and the analysis of dependable systems. Design examples for getting practical hands-on-experience in dependable design techniques. The module focuses towards embedded systems. The following topics are covered: • Modelling • Fault Tolerance • Design Concepts • Analysis Techniques
Literature	

Course L2001: Designing Dependable Systems	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Görschwin Fey
Language	DE/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 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 M0803: Embedded Systems

Courses

Title	Typ	Hrs/wk	CP
Embedded Systems (L0805)	Lecture	3	4
Embedded Systems (L0806)	Recitation Section (small)	1	2

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Computer Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models). Another part covers the hardware of embedded systems: Sonsors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy dissipation, reconfigurable logic and actuators. The course also features an introduction into real-time operating systems, middleware and real-time scheduling. Finally, the implementation of embedded systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy-efficient realizations, compilers for embedded processors) is covered.
Skills	After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge in which areas of embedded system design specific risks exist.
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	**Compulsory** Yes · **Bonus** 10 % · **Form** Subject theoretical and practical work · **Description**
Examination	Written exam
Examination duration and scale	90 minutes, contents of course and labs
	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory

Assignment for the Following Curricula	Electrical Engineering: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory Computational Science and Engineering: Core qualification: Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L0805: 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	EN
Cycle	SoSe
Content	• Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	• Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition, Springer, 2012., Springer, 2012.

Course L0806: Embedded Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0910: Advanced System-on-Chip Design (Lab)

Courses

Title	Typ	Hrs/wk	CP
Advanced System-on-Chip Design (L1061)	Project-/problem-based Learning	3	6

Module Responsible	Prof. Heiko Falk
Admission Requirements	None
Recommended Previous Knowledge	Successful completion of the practical FPGA lab of module "Computer Architecture" is a mandatory prerequisite.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	This module provides in-depth, hands-on experience on advanced concepts of computer architecture. Using the Hardware Description Language VHDL and using reconfigurable FPGA hardware boards, students learn how to design complex computer systems (so-called systems-on-chip, SoCs), that are commonly found in the domain of embedded systems, in actual hardware. Starting with a simple processor architecture, the students learn to how realize instruction-processing of a computer processor according to the principle of pipelining. They implement different styles of cache-based memory hierarchies, examine strategies for dynamic scheduling of machine instructions and for branch prediction, and finally construct a complex MPSoC system (multi-processor system-on-chip) that consists of multiple processor cores that are connected via a shared bus.
Skills	Students will be able to analyze, how highly specific and individual computer systems can be constructed using a library of given standard components. They evaluate the interferences between the physical structure of a computer system and the software executed thereon. This way, they will be enabled to estimate the effects of design decision at the hardware level on the performance of the entire system, to evaluate the whole and complex system and to propose design options to improve a 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, to transform this knowledge into actual implementations of complex hardware structures, and to associate this knowledge with contents of other classes.
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	VHDL Codes and FPGA-based implementations
Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computational Science and Engineering: Specialisation Information and Communication Technology: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L1061: Advanced System-on-Chip Design	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	6
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	• Introduction into fundamental technologies (FPGAs, MIPS single-cycle machine) • Pipelined instruction execution • Cache-based memory hierarchies • Busses and their arbitration • Multi-Processor Systems-on-Chip • Optional: Advanced pipelining concepts (dynamic scheduling, branch prediction)
Literature	• D. Patterson, J. Hennessy. Rechnerorganisation und -entwurf. Elsevier, 2005. • A. Tanenbaum, J. Goodman. Computerarchitektur. Pearson, 2001. • A. Clements. The Principles of Computer Hardware. 3. Auflage, Oxford University Press, 2000.

Specialization Microelectronics Complements

Students of the specialization Microelectronics Complements expand their knowledge towards the application of microelectronics and microsystems for medical use, the processing of digital signals, the development and design of highly complex integrated systems and networks for optical communication. Thus, they strengthen their knowledge by analyzing practical applications and link it up with the requirements of technical realizations.

Students have to choose lectures with a total of 18 credit points from the catalog of this specialization.

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 articifial 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 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

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/

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 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
	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology:

Assignment for the Following Curricula	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 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 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
	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology:

Assignment for the Following Curricula	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 M0925: Design of Highly Complex Integrated Systems and CAD Tools

Courses

Title	Typ	Hrs/wk	CP
CAD Tools (L0698)	Lecture	2	3
Design of Highly Complex Integrated Systems (L0699)	Lecture	2	3

Module Responsible	Prof. Volkhard Klinger
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	Oral exam
Examination duration and scale	40 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory

Course L0698: CAD Tools

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volkhard Klinger
Language	EN
Cycle	WiSe
Content	
Literature	

Course L0699: Design of Highly Complex Integrated Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volkhard Klinger
Language	EN
Cycle	SoSe
Content	
Literature	

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**	**Bonus**	**Form**	**Description**
	Yes	None	Presentation	
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 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

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