Karlsruher Institute of Technology

KIT – University of the State of Baden-Wuerttemberg and National Research Center of the Helmholtz Association

Department of Electrical Engineering and Information Technology

Description of Modules

15. April 2011

Course name	**Electromagnetic Fields and Waves**
Course code	**23055**
Associated Exercise	23057
Lecturer/ Institute	Prof. Trommer / ITE
Credit Points	6 + 3
Semester hours	4 + 2
Term	Winter term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	none
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	Fundamental lecture on electromagnetic fields and waves. Focus of the lecture are formal, methodical and mathematic fundamentals for understanding and calculating the phenomena of electromagnetic fields and waves.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises. Subsequently more dedicated assignments in form of tutorial sessions, in form of small study groups, are offered to deepen the understanding of the curriculum's as well as the exercises contents.
Contents	Lecture This course provides an introduction to the major theoretical foundations of electric and magnetic fields for students of the 3rd semester. In addition, the lecture is intended to be the basis for other application-related lectures. Basis of the lecture is the presentation of the electromagnetic field theory and the necessary mathematical methods. This is done on the basis of Maxwell's equation, which are presented and explained in detail in this lecture. Using this equation, the basic phenomena of electric and magnetic phenomena are calculated and explained. This includes the electrostatics, the stationary flow fields, strictly stationary magnetic fields, the inductive effects, quasistationary fields, the energy and energy flux density of fields, wave phenomena of fast varying fields up and finally the basics of antenna theory of the Hertzian dipole. Exercises To accompany the lecture material, assignments and the corresponding solutions will be given out and discussed during lecture hall exercises. Furthermore tutorials in small study groups will be held to deepen the understanding of the curriculum and methods taught. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The content of the lecture is distributed as a paper script. Online material on exercises is available on: www.ite.uni-karlsruhe.de/lehre There a most recent list of books is presented
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture, Exercises, and Tutorials

General remarks	The course comprises of the interleaved lecture blocks, exercises, and tutorials. Current information can be found on the ITE (www.ite.uni-karlsruhe.de) webpage.

Course name	**Computer Aided Circuit Design**
Course code	**23060**
Associated Exercise	none
Lecturer/ Institute	Dr.-Ing. Wolf/ITE
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Mathematical basics, basic knowledge in circuit design and semiconductor technology
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	Fundamental lecture for the computer aided design of integrated circuits. Main topics of this lecture are the network analysis and the topological design (layout). After introduction of mathematical, formal and methodical fundamentals the basic types of network analysis are discussed and several deterministic and stochastic algorithms for solving the Np complete layout problem are given.

Contents

Lecture

This lecture presents an introduction to the theoretical fundamentals of computer aided design of integrated circuits. Practical hints from engineering view are given.

First the development of the integration of integrated circuit over the years is given. The network analysis and layout as basic steps of the design process of integrated circuits are discussed in depth in the further lecture. The general layout problem belongs to the class of NP complete problems, therefore an introduction of a design methodology especially for VLSI circuits is needed.

After an introduction of the set theory the graph theory is formulated. This graph theory is needed as theoretical fundamental for the network analysis and layout.

For the network analysis a suitable description for the computer of the concerning circuit is presented. Next the classical network analysis methods and furthermore the analysis with state variables are discussed. For solving the network equations the well known procedures based on matrix inversion are discussed and then the here advantageous solution with LU factorisation is presented. After a short discussion of the analysis of nonlinear circuits the statistical tolerance analysis finishes the chapter of the network analysis.

In the next chapter layout, first the general layout problem is formulated. This is a typical combinatorical optimization problem which belongs to the class of NP complete problems. For this problem goal functions or cost functions and limiting boundary conditions are formulated. After introduction of a design methodology the design styles for integrated circuits are presented. According the principle “divide and conquer” the general layout problem is divided into placement and routing. For both of this two subproblems suitable deterministic and stochastic algorithms are presented after giving the concerning problem formulation for placement and routing.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	AT the ITE a script for this lecture is available.

Language	German
Examination	verbal (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the verbal examination
Course form	Lecture

Course name	**Introduction to Flight Physics, Guidance & Control**
Course code	**23062**
Lecturer/ Institute	Dr. Schöttl / ITE
Credit Points	3
Semester hours	2
Term	Summer Term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to convey basics about flight physics, guidance & control.
Brief description course	After presenting aerodynamic fundamentals, the forces and moments acting on a flying vehicle shall be explained. The resulting accelerations and turning rates shall be integrated through the discussed equations of motion. The control of flight states is necessary for a controlled flight; its fundamentals shall be discussed in the next sequel. Various types of flight guidance laws, which calculate the commands of the flight controller, shall be presented. The lecture shall end with an brief presentation on mission planning.
Brief description exercises	Examples and assignments to be completed for the next lecture shall be integrated in the course
Contents	Lecture This lecture presents an introduction to important basics of flight physics, guidance & control and represents a course part of a masters' curriculum. Since no aeronautic prerequisites are required, the lecture is divided into two parts. In the first part, the lectures shall include theoretical basics on aerodynamics such as potential flows and Navier-Stokes equations as well as the wing aerodynamics. The resulting forces and moments shall be modelled using flight physics; kinematic values – with respect to various coordinate systems – shall be calculated. In the second part, the lectures shall include theoretical foundations of flight physics, guidance and control. Aerodynamic coefficients shall be derived via linearization. The coefficients shall be used to describe the characteristics (e. g. the stability) of the vehicle in the lateral and longitudinal planes.The aerodynamical behaviour of a vehicle can be altered by introducing actuators within the system. Flight control calculates the necessary commands to achieve desired flight states. Simple flight controllers and their design shall be presented and discussed. The task of the flight guidance is to determine appropriate flight path commands in order to achieve certain flight goals. Typical designs (waypoint guidance and/or proportional navigation) shall be presented. The lecture shall end with an excurse on mission planning. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on the ITE web site. Further literature shall be presented in the lecture.
Language	German
Examination	Oral, prerequisite: provided correct solutions to the assignments
Formation of grade	Grades shall be based on results of a written examination
Course form	Laboratory
General remarks	Due to technical reasons, the number of available spaces is higher in the summer term than in the winter term.

Course name	**Analysis and Design of Multi-Sensor Systems**
Course code	**23064**
Lecturer/ Institute	Prof. Trommer / ITE
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to relay fundamentals of integrated navigation systems
Brief description course	This course's aim is to familiarise with the principles of fusing data of different and complementary sensors by the example of integrated navigation systems. The lecture gives an overview about a wide range of different sensor systems used in navigation systems especially accelerometers, gyroscopes and GPS.
Contents	This lecture presents the fundamentals of complex, integrated navigation systems. It presents both data fusion techniques and different sensor systems. First main topic of this lecture deals with fundamental functioning of different gyroscopes and accelerometers. The lecture delves into the fundamentals of ring laser gyroscopes and fibre optic gyroscope in detail. Afterwards micro mechanic sensors are introduced which are used more and more often in navigation systems due to low cost and increasing accuracy. Next topic deals with the strap down mechanisation, which integrates acceleration information and angular rate information to calculate absolute attitude, velocity, and position information. The strap down algorithm is derived from the differential equation of motion in detail. By means of integration of acceleration and angular rate measurements measurement errors cause an increasing navigation error. To prevent these errors additional aiding sensors has to be used. The Global Positioning System (GPS) is used most often. Therefore, this lecture concentrates on this system. Different aspects of GPS are mentioned and explained: GPS signal structure and acquisition and tracking of the GPS signal. Angular rate measurements, acceleration measurements as well as absolute GPS position and velocity measurements are fused by a Kalman filter to achieve the optimal position, velocity and attitude estimations. This lecture finally delves into the principle of Kalman filtering and the different techniques of sensor integration in an illustrative way. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.ite.uni-karlsruhe.de
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Principles of sensor fusion in integrated navigation systems**
Course code	**23069**
Lecturer/ Institute	PD Dr.-Ing. habil. Jan Wendel / ITE
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives Brief description course	The goal is to provide an insight into integrated navigation systems. Focus of the lecture are the fundamentals of inertial navigation and satellite navigation systems like GPS and Galileo. Data fusion algorithms, which are used in integrated navigation systems, are addressed as well.
Contents	This lecture provides an overview on the fundamentals of inertial navigation. Different types of accelerometers and gyroscopes are introduced, and the processing of their measurements by means of a strapdown algorithm is addressed. Then, the error characteristics of an inertial navigation system are analyzed. Next, the satellite navigation systems Galileo and GPS are discussed. Main emphasis is on the signal structure and the measurement of the time-of-flight of the satellite signal using PRN codes. The architecture of a typical receiver, its code and carrier tracking loops are analyzed. Different strategies for acquisition and tracking are treated, too. For the fusion of the information provided by the inertial sensors and the navigation reveiver, stochastic filters are used. Therefore, the Kalman filter equations are derived and discussed, followed by the design of a navigation filter. Different integration architectures like loosely, tightly, ultra-tightly and deeply coupled are addressed. Finally, further navigation techniques, which can be used to aid an inertial navigation system, are introduced. Examples are terrain referenced navigation and image based navigation. Additionally, advanced data fusion algorithms like sigma point Kalman filter, particle filter and covariance intersection, are analyzed and compared. Adaptive filters and strategies to cope with time-correlated measurement and process noise are investigated as well. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The supporting material will be distributed at the beginning of each lecture. Literature: Jan Wendel; Integrierte Navigationssysteme; Oldenbourg Wissenschaftsverlag GmbH, 2007.
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**System Optimization Laboratory**
Course code	**23071**
Lecturer/ Institute	Prof. Trommer / ITE
Credit Points	6
Semester hours	4
Term	Summer and Winter Term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	None Attending the lecture “Analysis and Design of Multi-Sensor Systems” is helpful.
Objectives	The goal is to apply gathered knowledge to practical problems.
Brief description exercises	Practical engineering problems are solved using modern software tools. The experiments cover the areas of laboratory fundamentals, image processing, automotive intelligence, satellite navigation systems and aerospace navigation.
Contents	The initial experiments cover an introduction to project management and the used software-tools (Matlab). The image-processing experiments investigate the extraction of different image features and the design of a system model to track objects in sequences of images. The section Automotive Intelligence covers the review of detection methods and the fusion of sensors detecting objects in passenger cars. Further experiments deal with the basis and extensions of the Global Positioning System (GPS). The implementation of an inertial navigational system and the integration of GPS/INS are studied in the section Aerospace Navigation. An additional experiment introduces to GPS Receiver Autonomous Integrity Monitoring. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Notes containing introductive material, detailed experiment descriptions and practice sheets are handed out in a preliminary meeting.
Language	German
Examination	Written and oral.
Formation of grade	The written part consists of submitting completed practice sheets, the oral part is a final colloquium. Grades result from both the written and oral point scores.
Course form	Laboratory
General remarks	Due to technical reasons, the number of available spaces is higher in the summer term than in the winter term.

Course name	**Basic Electronic Circuits Laboratory**
Course code	**23084**
Associated Exercise	--
Lecturer/ Institute	Dr. Teltschik / ITE
Credit Points	4
Semester hours	6
Term	Winter term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	Digital System Design (23615), Electronic Circuits (23655)
Objectives	Practical applications of analog and digital circuits design.
Brief description course	Nine laboratory exercises will help the students to apply their theoretical knowledge concerning basic electronic circuits design, as well as associated measurement and simulation techniques. The correct handling and interpretation of Semiconductor-Datasheets will also be trained.
Contents	The students will learn the handling of common laboratory test and measurement equipment like: oscillocope, waveformgenerator, multimeter, power supply. Measurements on basic circuit set-ups of operational amplifiers, bipolar transistors RC- and RL-Circuits will be accomplished. The control unit of a vending machine has to be developed by the students and built with digital logic devices. Basic computer-aided data acquisition techniques are taught by means of a LabVIEW experiment. A simulation exercise is used to teach electronic circuit simulation with several analysis options (transient analysis, DC-Sweep analysis etc.). The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Handout: „Elektrotechnisches Grundlagenpraktikum“
Language	German
Examination	Compulsory attendance and oral colloquium (certificate).
Formation of grade	No grading
Course form	Laboratory exercises

Course name	**Image processing for Navigation**
Course code	**23090**
Lecturer/ Institute	Prof. Link / ITE
Credit Points	3
Semester hours	2
Term	Summer Term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Linear agebra, calculus
Objectives	Basics of image and image sequence analysis
Brief description course	Abstract concepts of image analysis as an information source of autonomous systems (interpretation cycle for images and image sequences). Components for the extraction of information for the detection, recognition and analysis of objects and motion as well as spatial configuration.
Contents	The importance and the application of imaging sensors is increasing at still growing speed. Industrial inspection, security, robotics and automotive technology rely on machine vision to capture and understand the situation under consideration. The applications range from recognising and measuring objects to autonomous navigation of aircraft and vehicles. This trend towards more and more complex applications is not only driven by demand but also by the rapid progress of mathematical techniques, computers, communication and sensors. The course goal is to enable the students to create situation understanding solutions based on images and image sequences. The methodology of image and image sequence analysis is shown. The different components are presented in detail: Texture analysis, discontinuity (contours, edges, corners) detection, contour descriptions, shape analysis, motion analysis, imaging geometry, pose estimation, stereo imaging and sensor properties. The presented concepts are illustrated with examples from applications and on-line demonstrations. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Course slides can be downloaded from the internet. George Stockman, Linda G. Shapiro: Computer Vision, Addison Wesley Pub Co Inc, 2001 Hartley, Richard and Zisserman, Andrew: Multiple View Geometry in Computer Vision, Second Edition., Cambridge University Press, 2004 Jähne, B.: Digital Image Processing (third edition), Springer-Verlag London 1995
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Space Electronics and Telemetry**
Course code	**23093**
Lecturer/ Institute	Prof. Kaltschmidt / ITE
Credit Points	3
Semester hours	2
Term	Winter Term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Attending lectures about high frequency technology and information transmission technology is helpful.
Objectives	By means of system design problems it will be demonstrated how theoretical knowledge of the basic lectures of Electrical Engineering is used to get solutions for system design and component design.
Brief description course	The lecture with the focal point of space systems is structured in 5 chapters: Inroduction to Aerospace Engineering, Subsystems and Components, Satellite Information Transmission, Satellite Remote Sensing and Basics of Telemetry
Contents	Aerospace Engineering especially Space Elektronics having regard to Space Sensorics is highly complex and a most challenging technology. Operational satellite systems for communication navigation and remote sensing show the benefit based on aerospace research and development. Among other items the lecture deals with imaging sensorics in the infrared, visible and radiofrequent spectrum. Originally telemetry systems have been developed for testing aerospace systems. Today their application is manifold for example in aeronautics, mechanical engineering, (automotiv engineering) and biomedical engineering. By means of system design problems it will be demonstrated how theoretical knowledge of the lectures of high frequency engineering, system optimisation, measurement technology, communication engineering, information processing automatic control engineering and materials in electrical engineering is used to get solutions for system design and component design. Besides the technically scientifically conditioning there are examples of industrial applied methods for finding solutions of complex problems on the basis of integration sales and marketing, development, manufacturing financing, financial management and human resource management (man in charge, colleagues, cooperaters etc.) The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	Written
Formation of grade	Grades result from the written examination
Course form	Lecture

Course name	**Predictive Driver Assistance Systems**
Course code	**23096**
Associated Exercise	None
Lecturer/ Institute	Prof. Dr.- Ing. Peter M. Knoll / ITE
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Bachelor
Objectives	The goal is to relay an overview over predictive (Forward looking) driver assistance systems.
Brief description course	This lecture is the first part of a two-part lecture introducing into the field of “Driver Assistance Systems” often also named ADAS (Advanced Driver Assistance Systems). After defining and classifying these systems within the plurality of automotive assistance systems, at first the assistance systems needed for the realisation of predictive systems are explained. The first part of the lecture closes with a thorough explanation of the sensors necessary for a vehicle surround sensing.
Brief description exercises	None
Contents	Lecture This lecture represents an introduction to the Predictive Driver Assistance Systems, commonly named as Advanced Driver Assistance Systems (ADAS). A Bachelor degree is recommended as knowledge in Electrical Engineering is needed to understand the sensors, the system aspects and the algorithms applied in this field. At first, the lecture explains the meaning of ADAS, secondly, the motivation for their development is explained which can be derived from the huge accident avoidance potential given by these systems. The initiative of the EU for the reduction of street accident fatalities is explained as well as accident statistics and simulations for the quantification of the accident avoidance potential. Legal questions around ASAS close the first chapter of the lecture. Systems for wheel slip control, vehicle dynamic control systems, the brake assist and the steering assist are preconditions for ADAS and are discussed in short. In the field of passive safety systems restraint systems and pedestrian safety are discussed. The last chapter of this lecture deals with the surround sensors with Ultrasonic Sensors, Radar Sensors for the short and the long range, Lidar Sensors and Video sensors in CCD and CMOS technology in detail. The description of the different steps of picture processing and sensor data fusion closes this first part of the lecture. The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.ite.uni-karlsruhe.de/LEHRVERANSTALTUNGEN/prae_fahrer_ss.php.The material also contains literature links. A Bosch-publication „Driver Assistance Systems (also available in English) can be bought by the students at a preferred price.
Language	German
Examination	Oral, 20 minutes
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the ITE webpage (www.ite.uni-karlsruhe.de)

Course name	**Measurement**
Course code	**23105**
Associated Exercise	23107
Lecturer/ Institute	Prof. Puente / IIIT
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	Wahrscheinlichkeitstheorie, Komplexe Analysis und Integraltransformationen, Signale und Systeme
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	Measurement fundamental lecture. The lecture covers formal, methodical and mathematic fundamentals for the analysis and design of measurement systems. The focus thereby is on curve fitting, steady-state behaviour of measurement systems, stochastic measurement errors, correlational measurement and digitalization of analog signals.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.

Contents

Lecture

This lecture addresses bachelor students in the fifth semester of Electrical Engineering.

Firstly the terms measurement and characteristic measurement curve are introduced. Possible sources of measurement errors are presented and these errors are classified as either systematic or stochastic. In the course of the lecture, means to reduce both classes of errors are illustrated.

Since the characteristic curve of real world measurement systems is in general not given analytically, it must be derived from a set of given measurements. Therefore basic curve fitting schemes are discussed, including approximation (least squares) and interpolation (Lagrange and Newton polynomial interpolation, spline interpolation) methods.

Another part of the lecture covers the steady-state behaviour of measurement systems. Therefore the ideal characteristic curve, which is assumed for most measurement systems, is introduced and errors that arise hereby are evaluated. Afterwards, concepts to reduce these errors are presented for working both under specified normal conditions and with aberrations thereof.

In order to cope with stochastic measurement errors the basics of probabilistic theory are reviewed in short. As a new instrument to gain information about the unknown probability densities of the observed quantities, samples are introduced. Furthermore, parameter tests and goodness-of-fit tests as statistical hypothesis tests to prove/refute statements about these densities are presented.

As another powerful measurement tool, correlational measurement is subject matter of another part of the lecture and stochastic processes as necessary basics to this are went over in short. Based on it applications for transit time measurement and Doppler measurement are presented. The power-density spectrum is defined as the fourier transform of the correlation function and provides means for system identification. Also the Wiener filter as an optimal filter for signal reconstruction is covered.

Given that processing of real world measurements takes place mostly on digital computers, errors introduced by analogue/digital conversion are discussed for both the time- and amplitude-domain. Therefore the sampling- and quantization-theorem and means to fulfill both of them (anti-aliasing filter, dither) are presented as well as common ADC and DAC converter principles.

Exercises

To accompany the lecture material, assignments and the corresponding solutions will be given out and discussed during lecture hall exercises. Furthermore Weblearning Tasks are offered on the excersises' webpage, to provide a possibility for the students to test/deepen their understanding of relations between time-/frequency domain and time-signal/ACF respectively PDS.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Literature: F. Puente León, U. Kiencke, R. Eger; Messtechnik; 8. überarbeitete Auflage 2011. G. Lebelt und F. Puente; Übungsaufgaben zur Messtechnik und Sensorik
Language	German
Examination	Written
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IIIT (www.iiit.kit.edu) webpage.

Course name	**Distributed discrete event systems**
Course code	**23106**
Associated Exercise	none
Lecturer/ Institute	Prof. Puente / IIIT
Credit Points	4,5
Semester hours	3
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Probability theory, signals and systems
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	The lecture covers the theory basics needed to describe and analyze discrete event systems. The content of the lecture comprises following topics: Markov theory, queuing systems, max-plus algebra.
Contents	The lecture gives an introduction to the description and analysis of discrete event systems. The development towards industrial controllers demands for tools which help engineers to get analytical descriptions of automation systems and to handle with discrete event systems. In contrast to classical control, which is based on a unified system theory, discrete event systems are usually described in a variety of ways, such as queuing systems, Petri nets or automata, depending on the specific problem. The content of the course is divided into three parts. In the first section, the theory of Markov chains is presented. Markov theory is a classical framework for stochastic state model representation. Based on this theory, queuing systems or stochastic Petri nets can be described. Event processes, Markov processes, discrete time, and continuous time Markov chains are covered here in detail, among other topics. Next, the theory of queuing systems is presented. The queue theory handles the loading by customers with random arrival and service times of a limited capacity resource or server. Finally, the Max-plus Algebra is treated. If stochastic state transitions are assumed, discrete event systems can be successfully described with Markov chains. There are many other technical applications whose behaviour can also be described by state graphs, but in this case the state transitions need to be considered as deterministic. It is used for example in worst-case analysis, such as the maximum computing time of parallel and dependent programs, or the calculation of the minimum sum of path weights between two nodes within a digraph, e.g. the shortest travel time on a traffic network. The Max-plus algebra is a mathematical tool which permits to deal with such problems. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on www.iiit.kit.edu/ves.php. Literature: Uwe Kiencke: Ereignisdiskrete Systeme; Oldenbourg Verlag, 2. Auflage, 2006, ISBN 3-486-58011-6.
Language	German
Examination	Written (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination

Course form	Lecture.
General remarks	Current information can be found on the IIIT (www.iiit.kit.edu) webpage. The contents of the course described in this document are subject to modification without prior announcement.

Course name	**Signals and Systems**
Course code	**23109**
Associated Exercise	23111
Lecturer/ Institute	Prof. Puente / IIIT
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	Higher / Further Mathematics I + II
Objectives	The goal is to relay theoretical fundamentals of signal representation and system theory.
Brief description course	Signal processing fundamental lecture. The lecture focuses on the consideration and description of signals (time dependent variations of a measured variable) and systems. Different properties and methods of description are derived for the continuous-time and time-discrete case.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises. Additionally, the students can take advantage of weblearning in order to deepen parts of the subjects matter.

Contents

Lecture

This lecture presents an introduction to the important theoretical fundamentals of signal processing, which is scheduled for the students in the third semester of Electrical Engineering. After an introduction to functional analysis, research methods for signals are presented. Furthermore properties, description and design of systems are discussed. These considerations are made for continuous and discrete variation of time.

At first a common survey of the whole topic is given. Based on the lectures in further mathematics, more terms and definitions of functional analysis are introduced in the second chapter. Beginning with a repetition of linear vector spaces the important description of Hilbert spaces is established. Beyond that, we consider linear operators. These considerations help to get a general idea of the afterwards used methods.

In the following chapter we give attention to the consideration and description of continuous-time signals. The properties are regarded and the different ways of description are illustrated. Resources presented in the previous chapter are used to affiliate mathematical relations. Particularly considering the possibilities of spectral analysis, we respond to the description of signals by Fourier series or Fourier transform.

At the beginning of the forth chapter, general properties of systems are defined by means of the operator notation. Subsequently, system dynamics are described based on differential equations. To solve these equations, the Laplace transform can be used. To this end, the Laplace transform is derived from the Fourier transform, and its properties are presented. The treatment of windowing and the design of filters for continuous-time signals are two important sections. At the end of the chapter, the Hilbert transform is introduced.

Afterwards, time-discrete signals are discussed. The transfer is necessary, because in digital technology only discrete values can be used. At first, different conditions, essential for sampling and reconstructing analogue signals, are derived. Subsequent different methods for spectral analysis are regarded. Especially the Discrete Fourier Transform (DFT) plays a major role.

The last chapter focuses on time-discrete systems. At first, common properties of continuous-time systems are assigned to time-discrete systems. The specific features of discretization are discussed in detail. Afterwards, the mathematical description of time-discrete systems using difference equations and the z-Transform is presented. Further topics include the time-discrete representation of continuous systems and the effects of windowing. Finally, the introduced terms and definitions are illustrated based on several examples.

Exercises

Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises. Additionally the students can take advantage of weblearning in order to deepen parts of the subjects matter.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Literature: F. Puente León, U. Kiencke, H. Jäkel: Signale und Systeme; Oldenburg Verlag; 5., überarbeitete Auflage 2011. Studying material is available on the IIIT (www.iiit.kit.edu) website.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IIIT (www.iiit.kit.edu) webpage. The contents of the course described in this document are subject to modification without prior announcement.

Course name	**Automotive Control Systems**
Course code	**23110**
Lecturer/ Institute	Prof. Puente / IIIT
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic Mathematics, Automatic Control
Objectives	The goal is to relay theoretical fundamentals and to practice the scientific work process
Brief description course	The seminar covers the basic topics in the field of automotive control. Different topics are presented by groups of students in presentations and a final report. The students thereby practice the scientific work process. The topics cover the challenges of modern electronic engine control systems and vehicle modelling, the estimation of vehicle values and parameters as well as the ABS control system and the control of the yaw dynamics. Moreover current research topics of electric mobility are treated.
Contents	Seminar This seminar addresses students of Electrical Engineering with the fields of specialisation AI and MNO. The basics to understand modern control systems for combustion engines and vehicle stability are presented by groups of students. The first part of the seminar deals with the operations within the combustion engine of a vehicle. The principles of the inflammation of the air-fuel mixture and the flame propagation are discussed and the control of these operations is explained. In context of this topic the determination of optimal maps for fuel injection and ignition angle is illustrated. Furthermore the lecture deals with diesel engine modelling and in detail with the fuel injection and the cylinder dynamics. Afterwards the modelling of the whole driveline is explained. Based on the shown fundamentals the main aspects of the engine control systems lambda control, idle speed control, knock control and cylinder balancing are introduced. The second part covers vehicle modelling and vehicle control systems. At first a wheel model and the tyre characteristics are explained and a complete vehicle model is developed. An important part of modern vehicle control systems is the estimation of different values and parameters of a vehicle. The most important are the vehicle speed estimation, the observation of vehicle body sideslip angle and the identification of friction characteristic between tyres and road. Finally the vehicle control systems ABS control and the yaw dynamics control are presented. In the third part, current research topics of electric mobility are presented. The basics of hybrid and fuel cell vehicles are treated and problems of battery electric vehicles are regarded in detail. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	U. Kiencke, L. Nielsen: Automotive Control Systems – For Engine, Driveline, and Vehicle, 2nd edition, 2005
Language	English
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).

Formation of grade	Grades result from the presentation and the final report
Course form	Seminar

Course name	**Methods of Signal Processing**
Course code	**23113**
Associated Exercise	23115
Lecturer/ Institute	Prof. Puente / Institute of Industrial Information Technology
Credit Points	4,5 + 1,5
Semester hours	3 + 1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Signals and Systems, Measurement Engineering
Objectives	The goal is to convey advanced knowledge in the field of signal processing
Brief description course	Advanced signal processing lecture. The focus of the first part of the lecture is on time frequency analysis and synthesis. The second part of the lecture is about estimation theory.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solutions are presented and discussed during lecture hall exercises.
Contents	Lecture This lecture is offered to master students in electrical engineering and information technology who focus deeper in the field of signal processing and estimation theory. During the last years, time frequency analysis became an important part of signal processing theory. By means of time frequency analysis, signals with variable frequency content can be analyzed. Thus, time frequency analysis and synthesis are discussed in detail. The lecture also gives an extensive overview about parameter estimation and state estimation theory. The lecture starts with fundamentals on signal processing. The main signal properties are discussed. Signal representation in the Hilbert space is explained and different possibilities for signal representation in basis and frame are presented. Time frequency analysis is introduced by the short time Fourier transform (STFT). The wavelet transform, its application and realization as well as another time frequency distribution – the Wigner-Ville distribution – are discussed. The second part of the lecture is concerned with estimation theory. After fundamental considerations on signal modeling, parameter estimation techniques are introduced. Different estimators, like least squares, Gauß-Markov and so on are derived and compared. Subsequently, model based estimation and Bayes estimation is presented. The Kalman filter is discussed for state estimation. The lecture "Methods of Signal Processing" moderates advanced knowledge in signal processing and estimation theory. The theoretical considerations are exemplified by numerous examples of real applications. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Literature: Uwe Kiencke, Michael Schwarz, Thomas Weickert; Signalverarbeitung: Zeit-Frequenz-Analyse und Schätzverfahren; Oldenbourg Verlag; 1. Auflage 2008. Exercises and additional materials under www.iiit.kit.edu.
Language	German

Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and exercises
General remarks	The course consists of the interleaved lecture blocks and exercises. Current information can be found on the IIIT webpage (www.iiit.kit.edu). The contents of the course described in this document are subject to modification without prior announcement.

Course name	**Integrated Systems of Signal Processing**
Course code	**23125**
Associated Exercise	23127
Lecturer/ Institute	Prof. Dostert / IIIT
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Master
Elective course	Master
Prerequisites	Basic knowledge of signal processing theory and the corresponding implementation into hardware
Objectives	Advanced theoretical knowledge about modern digital signal processing methods and systems. Teaching of skills toward hardware realization of such systems with real-time capability.
Brief description course	The lecture addresses modern digital methods and according systems of signal processing, including elements, algorithms, hardware structures and special function units featuring real-time capability. Furthermore, the design of application specific integrated circuits using VHDL is treated toward the realization of embedded systems.
Brief description exercises	Accompanying the lecture, problems with practical relevance are presented. The solutions and the according methodology are derived in detail during lecture hall exercises. The exercises are intended to consolidate the material of the curriculum and to provide sophisticated skills toward practical application of the theory.
Contents	Lecture

Modern digital systems of signal processing (DSSP) are gaining more and more importance within RF and communication technology, process and control engineering as well as power electronics. Therefore, this lecture deals with elements, algorithms, hardware structures and special function units of corresponding systems with real-time capability. Since embedded systems based on application specific integrated circuits for signal processing become increasingly dominant, skills for the design of such circuits is an essential part of this lecture. Current sample applications in different areas, such as communication, complete this part.

As already today it is expected that most engineers are familiar with DSSP, this lecture addresses students of the master program in almost any of the possible studying directions.

To follow the lecture basic knowledge about signal processing and hardware implementation is a prerequisite. A goal of the lecture is advanced theoretical understanding of signal processing, as well as detailed explanation of the underlying real-time concepts. Moreover, the implementation into hardware is systematically taught. As a result, a solid foundation of DSSP skills is intended, both for the later professional working environment, and for further engagement in DSSP, like taking advanced lectures, or labs, or for completing a master’s thesis.

The first part of the lecture introduces analogue and digital components for signal processing as well as algorithms, software and protocols, required for real-time DSSP. Furthermore, RISC structures, special memory and bus systems, interrupt concepts and timer systems of advanced processors are explained.

The second part does not only consider the typical algorithms of signal processing, such as discrete convolution, correlation, filtering or DFT, but also the necessary hardware structures like parallel multipliers, squaring devices and MAC units. This part is completed by investigating concepts like pipelining, circular buffering, or zero-overhead looping, in order to understand the working principles of modern digital signal processors.

The third part of the lecture concentrates on special function units for DSSP. Such devices are used for signal synthesis, for digital mixing, or for modulation and demodulation purposes. In this context, FFT/IFFT processors, equalizers and filter structures are discussed. The application of multi-carrier techniques (OFDM) for data communication concludes this section.

Today, and especially for the future, it will not be sufficient to use programmable devices like MCs and DSPs for DSSP. A variety of features, preferably provided by ‘application specific integrated circuits’ become more and more important. Thus, methods to develop such application specific ICs are introduced. Based on VHDL modeling the use of FPGAs, gate arrays and cell-arrays is outlined. The presentation of development, simulation, verification and test tools completes the last part of the lecture.

Exercises

The exercises deal with various questions out of the curriculum of the lecture, being both essential for theoretical understanding and practical application. Assignments and the corresponding solutions will be given and discussed in detail during lecture hall exercises.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	The lecture script, supplements, and additional material are online available on: www.iiit.kit.edu/isvs.php. On this webpage also a list of related literature for further reading can be found.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and exercises
General remarks	The course comprises of interleaved lecture blocks and exercises. Current information can be found on the IIIT webpage (www.iiit.kit.edu). Due to the rapid progress in the development of modern ICs, the content of this lecture has to be continuously updated. So the course description given above can be considered as a framework, for which ongoing modifications and supplements will be provided.

Course name	**Digital Signal Processing Laboratory**
Course code	**23134**
Lecturer/ Institute	Prof. Puente / IIIT
Credit Points	6
Semester hours	4
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic mathematics, Probability theory, basics in signal processing
Objectives	The goal is to use the learned theoretical fundamentals.
Brief description course	The Digital Signal Processing Laboratory covers currently eight tasks to expose the students to the fundamentals of Digital Signal Processing, selected principles of measurement, e.g. Doppler and correlational measurement, the Kalman Filter and the fundamentals of image processing.

Contents

This laboratory addresses students of Electrical Engineering with the field of specialisation AI. The fundamentals of digital processing are used to solve eight different tasks. The first task is an introduction to the today's most important tools for digital processing Matlab and LabVIEW and the basis for further tasks. The following tasks deal with the main topics of digital signal processing.

The second task is to use the correlational measurement to determine run-time. Two mounted optical sensors measure signals which are used to suggest the run-time of bulk goods on a conveyor by means of correlation functions.

A further task is to analyze the effects caused by digital data acquisition, like aliasing, leakage effect and quantization noise.

An important part of digital signal processing is filtering. To deepen the understanding of analogue and digital filters, this task deals with this topic. The task is mainly focused on digital filters because of their import roll nowadays.

The following task is to determine the velocity of blood cells by the Doppler method. The blood cells have different velocities, so the recorded signal is made up of a whole spectrum of frequency displacements (Doppler spectrum). To analyze the signal a modern computer is used.

A powerful tool of signal processing is the Kalman filter. It is used for example to merge the data of different sensors. A possible application and the present task is the localization of a vehicle. Therefore incremental sensors at each wheel, two acceleration sensors for lateral and longitudinal direction and a yaw rate sensor are installed within the vehicle.

A part of the laboratory is the modal analysis. It is the most common method to analyze experimentally mechanical systems. The mechanical system used for this task is a thin steel plate which is excited by an impact hammer. The modes of the system are analyzed and the transfer function between the plate and a sensor is determined.

The last task is about the basics of image processing. The filtering of images, the edge detection, the correlation for image processing and the template-matching are the main issues of this task. The corresponding practical example is the visual quality control of circuit boards. These boards are recorded by a camera and analyze by the image processing tools of the program LabVIEW.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Kiencke, Jäckel: „Signale und Systeme“, Oldenbourg, 2008; Kiencke, Eger: „Messtechnik“, Springer-Verlag, 2008; Kiencke, Schwarz, Weickert: „ Signalverarbeitung“, Oldenbourg, 2008
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Laboratory
General remarks	The contents of the laboratory described in this document are subject to modification without prior announcement.

Course name	**Microcontroller and DSP Processor Laboratory**
Course code	**23135**
Associated Exercise	none
Lecturer/ Institute	Prof. Dostert / IIIT
Credit Points	6
Semester hours	4
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic knowledge out of German courses “Integrierte Signalverarbeitungssysteme”, “Signale und Systeme”,” Messtechnik” and “Nachrichtenübertragung” is helpful. However, since the fundamentals are also summarized in the lab’s documentation material, it is not compulsory to have taken part in the above courses ahead of the laboratory.
Objectives	The intention of this lab is to make the participants familiar with different programmable processors, their architectures and On-Chip peripherals. Also programming of application-specific hardware in the form of FPGAs is covered. The lab teaches how to program these devices toward real-time capability within basic and advanced signal processing applications.
Brief description course	Six experiments are executed during this laboratory. A student group consists of three persons, conducting one experiment. Two independent sets of equipment are available for each experiment, so that the resulting capacity will be 36 students per course.
Contents	Laboratory The lab focuses on typical digital processing tasks to be executed by PCs, microcontrollers (MCs), digital signal processors (DSPs) or field programmable gate arrays (FPGAs). The experiments 1 and 2 deal with MC-based real-time applications. The rotation speed of a motor will be measured and displayed by the system in experiment 1. Experiment 2 uses the same MC system to synthesize a selection of periodical signals digitally. The experiments 3 and 4 are DSP processor applications. Identification and compensation of unbalanced mass is a common problem in metal or glass plate fabrication. Experiment 3 introduces a least-mean-square (LMS) algorithm-based method to locate the unbalanced mass using a DSP processor and ‘Matlab’ on a PC platform. Experiment 4 deals with audio signal processing. Filters will be designed to generate echoes and to suppress different kinds of noise, including narrowband interferers. Experiment 5 provides a simulation platform developed under Matlab/Simulink, with which basic features of digital communication systems such as the signal-to-noise ratio (SNR) and the bit error rate (BER) are studied. Pros and cons of commonly used modulation schemes will also be investigated, evaluated, and discussed.

	Field programmable gate arrays (FPGAs) are gaining more and more importance, e.g. in communication, automotive or medical applications. Therefore, experiment 6 presents the usage of an FPGA for a typical and challenging signal processing task. The analog signal is sampled and reconstructed by on-board AD/DA converters. The FPGA will have to be programmed to control the AD/DA converters, to manage the data flow, and to execute various signal conditioning algorithms. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	All lab documentation and teaching material is available under: http://www.iiit.kit.edu/pmcdsp.php
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the evaluations of the individual experiment’s protocols and a written examination with equal weight
Course form	Laboratory, face-to-face tutorial
General remarks	Current information can be found on the IIIT (http://www.iiit.kit.edu) webpage. Due to rapid progress in the development of modern ICs, the lab documentation has to be continuously updated. Thus, the description given above has to be considered as a framework, for which ongoing modifications and supplements will be provided.

Course name	**Interference-resistant Communication**
Course code	**23136**
Associated Exercise	**23138**
Lecturer/ Institute	Prof. Dostert / IIIT
Credit Points	4.5 + 1.5
Semester hours	3 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic knowledge of information and communication system theory as well as RF engineering
Objectives	Advanced theoretical knowledge and practical approaches for the design of robust communication systems to exploit unusual channels, such as energy distribution grids.
Brief description course	Basics of information and communication system theory as well as RF engineering and measuring technology are collected and presented in form of a concise overview. Starting from this, advanced concepts for robust and interference resistant data transmission over unusual channels are derived. According realizations in hard- and software are presented for various typical cases.
Brief description exercises	Accompanying the lecture, problems with practical relevance are presented. The solutions and the according methodology are derived in detail during lecture hall exercises. The exercises are intended to consolidate the lecture material and to teach skills toward practical applications of the theory.
Contents	Lecture The lecture is based on the knowledge acquired with the Bachelor degree at the KIT. At the beginning, continuous time-domain signals are considered, as well as the behavior of LTI systems under the influence of such signals. The continuous time convolution is introduced in order to describe the relation between the output signal of a system, the system’s impulse response, and the input signal. All these relations are then transferred to time-discrete signals and systems. Furthermore, correlation is introduced for determinate (energy) signals, and the relation between correlation and convolution is explained. In a next step methods to describe stochastic signals are presented, and the corresponding parameters which are relevant for such signals are introduced. The relevance of the correlation function for stochastic signals is explained. Based on this theoretical background, the principle of correlation-based matched filter receivers is illustrated. A further step within the lecture describes the behavior of transmission lines when high frequency time-continuous signals are applied. The underlying model of transmission line theory is explicated and parameters such as characteristic impedance, attenuation and reflection are introduced as a general base. Then modifications are elaborated, in order to extend and adapt the theory to unusual wiring structures, which were not designed for communication purposes, but e.g. solely for transmission of electrical energy. As an analytical treatment of such wiring structures will usually not be possible in practice, special and dedicated measuring methods are investigated for parameter acquisition and modeling of the line properties.

Important additional steps toward the analysis of data transmission quality are the evaluation of ‘throughput’ (i.e. data rate) and bit error rate (BER). In order to treat this topic, it is necessary to revisit the basics of probability theory, i.e. distribution function, density function, statistical independence etc.

Starting from this common base, the behavior of LTI systems influenced by Gaussian random processes is investigated, leading to results for BER figures in matched filter receivers. Eventually these considerations represent an essential step toward the explanation of the term ‘channel capacity’. Then, in advanced studies the mentioned unusual channels are thoroughly examined, defining possibilities limitations of their usability.

As typical and highly challenging examples, energy distribution grids are considered as channels for reliable data transmission. Such aspects are currently of special interest for the realization of so-called ‘Smart Grid’ and ‘Smart Metering’ issues. The general goals are improvements of efficiency for the usage of electrical energy, especially for the optimal distribution of energy from renewable sources (wind, photo-voltaic), as well as permanent supervision and surveillance of the power grid.

For various reasons, the power lines themselves are the first choice for data transmission. Therefore, in the final part of the lecture the whole theoretical background acquired during the previous sections is now evaluated in order to select the best methods for the exploitation of these unusual channels. In this context multicarrier signaling in the form of OFDM is considered and judged, as well as different spread spectrum technologies.

Exercises

Selected problems with practical relevance are given, in order to improve the understanding of important topics of the lecture. The intention is to bridge the gap between theoretical background and practical applications. Solutions and the according methodology are taught in detail during lecture hall exercises.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	The lecture script, supplements, and additional material are available online under http://www.iiit.kit.edu/sri.php. On this webpage also literature for further reading can be found.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and exercises
General remarks	Current information can be found on the IIIT webpage (www.iiit.kit.edu). Due to the rapid progress in the development of modern hardware, the content of this lecture has to be continuously updated. Thus, the description given above can be considered as a framework, for which ongoing modifications and supplements will be provided.

Course name	**Informationtechnology in industrial automation**
Course code	**23144**
Associated Exercise	-
Lecturer/ Institute	Dr.-Ing. Bort / IIIT
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	Practically oriented cross section lecture information technology and automation technology. The lecture focuses on the interdisciplinary interactions and interrelationships of modern automation systems over their whole product life cycle. The lecutre examines not only technical, but also economic, political and company specific constraints.
Contents	Lecture The lecture provides an introduction to modern automation systems. Starting from simple PLC systems, complex Control and Manufacturing Execution Systems (MES) up to Enterprise Resource Planning (ERP) Systems. The lecture examines different industries, technologies and standards which are used in such complicated systems.. Another focus of the lecutre is plant engineering and system integration. Different modelling approaches and tools for plant engineering are introduced and the specific features of the system integration in plant automation are examined, as for example the high number by different interfaces, the different life cycles of single components, subsystems and plant components or the extreme requirements for the safety and availability of the plants. Economic aspects play a central role in all cases of the lecture. On the basis of numerous practical examples the student should develop a feeling for the economic effects of engineer's decisions from developer view and from operating authority view by themselves. In this context subjects are treated like asset management and strategies for plant engineering and plant operation. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Skript
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**System Dynamics and Control Engineering**
Course code	**23155**
Associated Exercise	23157
Lecturer/ Institute	Prof. Hohmann / IRS
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	Integral Transformations
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	System Dynamics and Control fundamental lecture. This lecture familiarizes students with the basic elements, structures and the behaviour of dynamic systems. It gives them insight into the problems of control and intuition about methods available to solve such problems. Both frequency response and state space methods for analysis and design of dynamic systems are considered.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises. Subsequently more dedicated assignments in form of tutorial sessions, in form of small study groups, are offered to deepen the understanding of the curriculum's as well as the exercises contents.

Contents

Lecture

Introduction: overview and definitions, open-loop and closed-loop control, design process for control systems;

Classification and Description of control circuit elements: introduction and basic concepts, block diagram, behaviour of elementary control circuit elements, standard control circuit and block diagram transformations, structure of digital control circuits, description of digital control circuits, simulation of time continous control circuits;

Analysis of linear control circuits in continous time: steady-state behaviour and characteristic signals, polar plot (Nyquist diagram), Bode diagram, basic concepts of stability, algebraic stability criteria, graphic stability criteria;

Analysis of linear control circuits in discrete time: steady-state behaviour, polar plot (Nyquist diagram) and Bode diagram, basic concepts of stability, algebraic stability criteria, graphic stability criteria;

Synthesis of linear control circuits in continous time: control circuit requirements, direct methods, controller design using the Bode diagram, controller design using the root locus, heuristic controller design, feed forward control, secondary control and cascaded control;

Synthesis of linear control circuits in discrete time: fast sampling design, direct methods, controller design using the Bode diagram and the root locus.

Exercises

To accompany the lecture material, assignments will be given out and discussed during lecture hall exercises. Furthermore tutorials in small study groups will be held to deepen the understanding of the curriculum and methods taught.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Supplemental sheets for the lecture are available on the IRS webpage. Literature: a) Föllinger, Otto: Regelungstechnik, 10. Auflage, Hüthig-Verlag 2008 b) Lunze, Jan: Regelungstechnik I, 7. Auflage, Springer-Verlag 2008. Furthermore computer demonstrations in Matlab/Simulink used in the lecture for visualization of the presented topics can be downloaded from the IRS webpage for own experiments.
Language	German
Examination	Written
Formation of grade	Grades result from the written examination
Course form	Lecture, Exercises and tutorials
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IRS webpage.

Course name	**Automation of Discrete Event and Hybrid Systems**
Course code	**23160**
Lecturer/ Institute	Dr. Kluwe / IRS
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Prerequisites	Bachelor/Master
Objectives	In the lecture the students get familiar with the basics of the modelling, simulation, analysis and control of discrete event and hybrid systems.
Brief description course	The course trains students in basic topics on discrete event systems. It qualifies students to develop different discrete event process models and to select the appropriate model for a given problem. It also familiarizes students with simulation and analysis of presented model concepts. A major topic of the course is discrete event controller design, including specification as well as implementation issues. An introduction to hybrid systems provides self-studying ability on this topic of increasing importance in control engineering.
Contents	Lecture Introduction: System classification, Definitions, Examples; Model Classification and Modelling Formalisms: Automata and formal languages, Petri nets, Net-Condition/Event-systems; Discrete Process Modelling: State oriented modelling, resource oriented modelling; Analysis of Discrete Event Systems: Properties of Petri nets, Analysis of Petri nets, Analysis of timed Synchronisation Graphs with Max-Plus-algebra; Specification and Design of Discrete Controllers: Classification of control objectives and controllers, Specifications of the controller, Controller design, Implementation, Examples; Hybrid Systems: Hybrid phenomenas, The Net-State-Model, Simulation, Analysis and Control of hybrid systems, Example The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Supplemental sheets for the lecture are available on the IRS webpage. Literature: a) Cassandras, C. G., Lafortune, S.: Introduction to Discrete Event Systems, Springer-Verlag 2008 b) Abel, D.: Petri-Netze für Ingenieure, Springer Verlag 1990. Furthermore demonstrations in Matlab/Simulink and with an own SW-tool for discrete event systems (DESSKA) are used in the lecture for the visualization of the presented topics and can be downloaded from the IRS webpage for own experiments.
Language	German
Examination	mündlich
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the IRS webpage (http://www.irs.kit.edu/).

Course name	**Modelling and Identification**
Course code	**23166**
Associated Exercise	23168
Lecturer/ Institute	Prof. Hohmann / IRS
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Prerequisites	Bachelor/Master
Objectives	The goal of the lecture is to impart knowledge about the theoretical and experimental modelling of dynamic systems.
Brief description course	Lecture that deals with the fundamental engineering duty of modelling technical processes. This comprises as well the theoretical modeling based on the physical analysis leading to the equations of the process as the identification as the experimental determination of its parameters.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.

Contents

Lecture

Introduction: System design (System design based on requirements, heuristic system design, Model based system design), Modelling process (Top-Down approach, Validation and verification, Classes of models, Bottom-up approach);

Structuring: Overview, Structuring with Matlab/Simulink, Structured analysis);

Generalized equivalent circuit diagrams: Generalized Variables, Basic system elements (electrical and magnetic systems, mechanical systems, fluid systems. multi-port systems), interconnection rules;

Theoretical Modelling: Generalized network method, Variational method, Building of State space equations;

Identification with non-parametric models: Frequency response analysis, correlation analysis;

Identification with parametric models: Overview, Parameter identification, model adjustment methods, Least-squares method for static processes, Least-squares method for dynamic processes, Instrumental variables method, Maximum Likelihood method.

Exercises

To accompany the lecture material, assignments will be given out and discussed during lecture hall exercises.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Supplementals for the lecture are available on the IRS webpage (http://www.irs.kit.edu/). Literature: Wellstead, P.E.: Physical System Modelling. Academic Press 1979.
Language	German
Examination	oral
Formation of grade	Grades result from the oral examination.
Course form	Lecture and Exercises

General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IRS webpage (http://www.irs.kit.edu/).

Course name	**Stochastic Control Systems**
Course code	**23171**
Lecturer/ Institute	Dr. Kluwe / IRS
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Prerequisites	Bachelor/Master
Objectives	The goal is to relay theoretical and practical fundamentals on the field of optimal estimation of stochastic process signals.
Brief description course	This course prepares the students to solve the optimal state estimation problem in dynamic systems, which is a demanding engineering task in industrial control applications. Starting with the fundamentals of stochastics, the broad theory of Wiener Filters and Kalman(-Bucy) Filters is presented, so that the student is enabled to design and analyze such filters. Moreover, nonlinear filter concepts are discussed.
Contents	Stochastic Processes: random variables, probability distribution and density, conditional probability distribution and density, independent stochastic processes, Markov processes, mean values: correlation and covariance function, stationary and ergodic processes, power spectrum, normal processes and white noise; Systems with stochastic inputs and outputs: time-invariant systems and stationary processes, time-variant systems and instationary processes; Optimization of linear systems with stochastic inputs and outputs: general estimation problem, structure of the optimization problem, filtering, prediction and interpolation; Optimal state estimation by Wiener Filters: optimization by structure optimization, Wiener-Hopf equation, orthogonality principle; Optimal State Estimation by Kalman Filters: maximum-a-posteriori and minimal-variance estimation, filtering and prediction equations of Kalman Filters, structure and features of Kalman Filters, application examples and computer demonstration, comparison with deterministic least-squares-optimization; Optimal State Estimation by Kalman-Bucy Filters: estimation equations of Kalman-Bucy Filters, structure and features of Kalman-Bucy Fiters, examples; Outlook: Nonlinear Filters: Extented Kalman Filter, Sigma-Point Kalman Filter. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Supplemental sheets for the lecture are available on the IRS webpage. Literature: a) Papoulis, A.: Probability, Random Variables and Stochastic Processes, 3rd edition, McGraw-Hill 1991. b) Krebs, V.: Nichtlineare Filterung. Reprint of the book published 1980 by Oldenbourg. Furthermore, the demonstrations in Matlab/Simulink used in the lecture for visualization of the presented topics can be downloaded from the IRS webpage (http://www.irs.kit.edu/) for own experiments.
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture

General remarks	Current information can be found on the IRS webpage (http://www.irs.kit.edu/) .

Course name	**Nonlinear Control Systems**
Course code	**23173**
Lecturer/ Institute	Dr. Kluwe / IRS
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Prerequisites	Bachelor/Master
Objectives	The goal is to relay theoretical and practical fundamentals on the field of nonlinear control.
Brief description course	Advanced lecture in the field of nonlinear System Dynamics and Control that teaches students to carry out description, analysis and synthesis of nonlinear control systems.
Contents	Basics: Nonlinear systems (definition, description and typical structures), stability of nonlinear systems; Analysis and synthesis of nonlinear systems in the phaseplane: principles, trajectories of the nonlinear control-loop and stability of equilibrium points, Lyapunov-stability of nonlinear systems: principle of Lyapunov's stability theorem, stability criterias, additional criterias for stability and instability, stability analysis, Lyapunov's stability theorem for linear and linearized systems; Synthesis of nonlinear systems in state space: Exact feedback linearization of nonlinear SISO- and MIMO-systems; Harmonic Balance: Describing Function and the harmonic balance equation, Describing Function and the nonlinear polar plot, detection of oscillations with the harmonic Balance, stability of oscillations and equilibrium points Popov criterion: Absolute stability and prerequisites of the Popov criterion, Definition and application of the Popov criterion, extensions and boundaries of the Popov criterion The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Supplemental sheets for the lecture are available on the IRS webpage. Literature: a) Föllinger, Otto: Nichtlineare Regelungen (Band I und II). 8. Auflage, Oldenbourg Verlag 1998. b) Khalil, H.K.: Nonlinear Systems. Prentice-Hall 2001. c) Isidori, A.: Nonlinear Control Systems.,Third edition, Springer Verlag 2001. Furthermore, the demonstrations in Matlab/Simulink used in the lecture for visualization of the presented topics can be downloaded from the IRS webpage (http://www.irs.kit.edu/) for own experiments.
Language	German
Examination	Written
Formation of grade	Grades result from the written examination
Course form	Lecture
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IRS webpage (http://www.irs.kit.edu/).

Course name	**Advanced Control Techniques Laboratory**
Course code	**23175**
Lecturer/ Institute	Prof. Hohmann / IRS
Credit Points	6
Semester hours	4
Term	Winter term
Bachelor/ Master	Bachelor/Master
Prerequisites	Bachelor/Master
Objectives	The goal of the laboratory is the practical application of the methods in system dynamics and control engineering given in the lectures of the IRS within the master curriculum.
Brief description course	Students will be introduced into practical, modern control concepts. They apply methodologies ranging from classical controller design to fuzzy, neural, nonlinear, and discrete event concepts to real world plants, where they are confronted with practical issues and problems. They will be capable to analyze a process under consideration and to decide in a systematic way which control strategy is appropriate satisfying given control objectives.
Contents	Simulation Techniques: Introduction to MATLAB/SIMULINK, Digital Simulation, Controller implementation using Rapid Prototyping (dSPACE9; Multivariable Control of a Test Stand for a Car Rear Axle: PI-Controller, Decoupling controller, PI-state space controller; Discrete Event Control of a Manufacturing Plant: Process modelling and controller design with Petri nets, Controller specification using IEC 1131, System analysis based on Petri net theory; Control of a Three Tanks system: Control by compensation, Fuzzy controller, Neuro controller; Control of a Loading Crane: Theoretical modelling and parameter identification, Pole assignment controller design, Luenberger observer design, Riccati controller design, Robust Control Design; State estimation of a “Ball and Beam” plant: State space estimation methods, Kalman Filters, Sigma-Punkt Kalman Filters, Introduction in LabView, Controller design for the “Ball and Beam” plant The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	For each of the experiments of the lab there is a comprehensive script including the description of the equipment, its theoretical basics and some problems which have to be solved before and also during the lab.
Language	German
Examination	oral
Formation of grade	Grades result from the oral examination and the written protocols for each experiment.
Course form	Laboratory
General remarks	Current information can be found on the IRS webpage (http://www.irs.kit.edu/).

Course name	**Control of multivariable linear Systems**
Course code	**23177**
Associated Exercise	23179
Lecturer/ Institute	Dr. Kluwe / IRS
Credit Points	4,5 + 1,5
Semester hours	3 + 1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Prerequisites	Bachelor/Master
Objectives	The goal is to impart knowledge about advanced methods for the modelling, analysis and control of multivariable systems.
Brief description course	The course teaches students basic knowledge and skills to analyze linear multivariable dynamic systems (described both in continuous and discrete time) and to design linear controllers and observers. The students are enabled to apply these methods in order to solve practical controller design problems like poor sensor information or disturbances and uncertainties. The students get familiar with the design of dynamic feedback controllers and learn how to achieve robustness.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.
Contents	Lecture Modelling of linear systems: time- and frequency-based I/O-models, state-space models; Analysis of linear systems: stability, Controllability and Observability, Zeros and poles; Control synthesis of I/O-models: Decoupling control in frequency domain; Control synthesis of state space models: Principle structures and basic concepts of feedback control, Special concepts of feedback control: Riccati control, Modal control, Input-Output-Decoupling and Parametric state feedback design of Roppenecker, Deadbeat control; Synthesis of State space Observers: Luenberger observer, Reduced observer; Synthesis of Controllers for disturbed Systems: Compensation of disturbances, Disturbance models, PI state space controller; Synthesis of Output Feedback Controllers: Equations and structure; Parametric output feedback design of Roppenecker; Synthesis of Dynamical State Space Controllers; Synthesis of robust Controllers by Pole area placement: Definition and Pole area stability, Pole area placement (method of Konigorski), Design of robust output feedback controllers; Reduction of the order of high-order models: Problem and principle, modal order reduction, Construction of the reduced model (method of Litz); Exercises To accompany the lecture material, assignments will be given out and discussed during lecture hall exercises. The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Supplemental sheets for the lecture are available on the IRS webpage. Literature: a) Föllinger, Otto: Regelungstechnik, 10th edition 2008. b) Lunze, Jan: Regelungstechnik 2. 6th edition, Springer 2010. Furthermore the demonstrations in Matlab/Simulink used in the lecture for visualization of the presented topics can be downloaded from the IRS webpage (http://www.irs.kit.edu/) for own experiments.
Language	German
Examination	Written
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IRS webpage (http://www.irs.kit.edu/).

Course name	**Optimization of Dynamic Systems**
Course code	**23183**
Associated Exercise	23185
Lecturer/ Institute	Prof. Hohmann / IRS
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Master
Prerequisites	Master
Objectives	The goal is to relay methods for the optimization of dynamic systems.
Brief description course	The lecture has still to be defined in more detail.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.
Contents	Lecture Topics has still to be defined. Exercises To accompany the lecture material, assignments will be given out and discussed during lecture hall exercises. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Supplements for the lecture are available on the IRS webpage (http://www.irs.kit.edu/).
Language	German
Examination	Written
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IRS webpage (http://www.irs.kit.edu/).

Course name	**Special lecture Prof. Hohmann**
Course code	**23184**
Associated Exercise	23186
Lecturer/ Institute	Prof. Hohmann / IRS
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Prerequisites	Bachelor/Master
Objectives	The goal of the lecture has still to be defined.
Brief description course	The lecture has still to be defined in more detail.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.
Contents	Lecture Topics has still to be defined. Exercises To accompany the lecture material, assignments will be given out and discussed during lecture hall exercises. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Supplements for the lecture are available on the IRS webpage (http://www.irs.kit.edu/).
Language	German
Examination	Written
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IRS webpage (http://www.irs.kit.edu/).

Course name	**Model Predictive Control**
Course code	**23188**
Lecturer/ Institute	Dr. Pfeiffer / Siemens AG
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Prerequisites	Bachelor/Master
Objectives	The goal is to relay theoretical and practical fundamentals on the field of control methods in distributed control systems and Model Predictive Control.
Brief description course	Students attending this lecture will obtain the theoretical background to apply Model Predictive Control and asses its advantages as well as its limitations. Three lectures will give the opportunity to hands on training and familiarize students with standard industry software.
Contents	Introduction: Requirements of modern Automation Systems, Standards of Local PID-Control, Advanced control methods; Architecture of modern process control systems, Advanced PID-Structures; Tutorial Part I: PCS 7; Principles of Model-based Predictive Control (MPC): Basic definitions (Modelling, Prediction, Optimization, Moving Horizon), Internal Model Control (IMC), General Structure of MPC; Mathematical modelling and Identification of processes: Linear models, Nonlinear models, Suitability for MPC; Tutorial Part II: MPC Engineering and Process identification; MPC Approaches and Methods: Glossary, MPC for linear processes, MPC for nonlinear processes; Online-Optimization for MPC: Linear Programming, Quadratic Programming; Realization and Implementation of MPC: Commercial Software tools, Integration in process control systems; MPC: Application and settlement of project: Conception , Installation and Test, Modelling, Controller design, Acceptability test, Maintenance; Application examples: Distillation Column, Glass melting Process, Polymerization reactor; Tutorial Part III: Predictive Control of distillation column The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Literature: a) Dittmar, R., Pfeiffer, B.-M.: Modellbasierte prädiktive Regelung. Oldenbourg Verlag 2004. b) Camacho, E. F., Bordons, C.: Model predictive control. Springer 1999. c) Garcia, C. E., Prett, M., Morari, M.: Model predictive control: theory and practice – a survey. Automatica 25 No. 3, pp. 335-348, 1989. d) Bergold, S.: Methoden zur Regelung von Mehrgrößenprozessen in der Verfahrenstechnik, Dissertation of the Universität Kaiserslautern, D386, 1999.
Language	German
Examination	oral
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	The course comprises of the interleaved lecture blocks and tutorial parts. Current information can be found on the IRS webpage (http://www.irs.kit.edu/).

Course name	**Passive Components**
Course code	**23206**
Associated Exercise	23208
Lecturer/ Institute	Prof. Ivers-Tiffée / IWE
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Bachelor
Bachelor/ Master	Bachelor
Prerequisites	none
Objectives	The objective of the lecture is to impart students the fundamental ideas of passive components.
Brief description course	The lecture concerns the fundamental ideas of the electrical properties of materials. It is designed to provide students with an understanding of the close interaction between the development of new materials and the emergence of new technologies and technical applications.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.
Contents	Lecture Materials play a decisive role in technological progress, especially in key technologies such as electrical engineering and information technology or environmental engineering. Based on a survey of the structure of atoms and solids and the fundamental electrical conduction mechanisms, this lecture provides an overview of the electrical properties of materials with regard to their applications in passive components. The lecture focuses on metallic and non-metallic conductors and their components (e.g., non-linear resistors such as NTC, PTC, or varistors), the polarization mechanisms in dielectrics and their applications, e.g., capacitors, piezo-/ferroelectrics, as well as on magnetic materials and their applications (coils, storage media). The imparted knowledge serves as a basis of decision for all engineers working in research and development in their respective area of responsibility. It is therefore of interest for all students regardless of their field of specialisation. In addition, the content of this lecture forms the foundation for all of the continuative courses of our field of specialisation. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available at http://www.iwe.kit.edu; Literature: Ivers-Tiffée, von Münch: Werkstoffe der Elektrotechnik. 10th edition, Teubner 2007.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises lectures and exercises. Current information can be found on the IWE website (http://www.iwe.kit.edu).

Course name	**Batteries and Fuel Cells**
Course code	**23207**
Associated Exercise	23213
Lecturer/ Institute	Prof. Ivers-Tiffée / IWE
Credit Points	3+1.5
Semester hours	2+1
Term	Master
Compulsory course	Master
Prerequisites	Lecture Course “Passive Components”. Basic understanding of electrochemistry and thermodynamics.
Objectives	This course is aimed at giving seniors in electrical engineering an understanding of the structure and operating principles of electrochemical energy storage (batteries) and conversion (fuel cells) systems.
Brief description course	This lecture covers the thermo dynamical and electrochemical basics of fuel cells and batteries as well as methods for electrical characterization and modeling. Moreover, applications within transportation and energy technologies as well as in electrotraction are addressed.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed.
Contents	The course provides an overall picture of fuel cells and batteries currently used in innovative environmental and energy conversion applications. The lecture is divided in three parts. Firstly, fundamentals of thermodynamics and electrochemistry are presented and the losses associated with transport processes during energy conversion are treated. The second part of the course covers the structure and operating principles of fuel cells as well as the most important approaches in electrical characterization and modeling. Applications in mobile and stationary systems in the mobility and in the energy sector are discussed (low-temperature fuel cells as energy source in electric vehicles, high-temperature fuel cells in the decentralized power supply). The last section deals with electrochemical energy storage, the focus being on high-energy batteries for electrotraction (e.g., lithium-ion battery, sodium-nickel chloride battery). Current developments leading to an enhancement of power densities are presented, as well as the electrical characterization and modeling of batteries. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on http://www.iwe.kit.edu; Literature: - Lecture notes - A. Heinzel et al. (Eds.), Brennstoffzellen: Entwicklung, Technologie, Anwendung, 3rd ed., Heidelberg: Müller, 2006 - L. F. Trueb, P. Rüetschi, Batterien und Akkumulatoren, Springer, 1998
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture and Exercises
General remarks	The course comprises lectures and exercises. Current information can be found on the IWE website (http://www.iwe.kit.edu).

Course name	**Systematic Product Development in the Sensor Technology**
Course code	**23209**
Lecturer/ Institute	Dr.-Ing. Riegel / IWE
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	None
Objectives	This course is aimed to give seniors in electrical, mechanical and economics engineering an understanding how modern development of sensors takes place in the automotive industry. The course is also aimed to give an overview of quality management methods during development processes.
Brief description course	The students should receive a survey of the most important exhaust gas sensors and of the different steps in the design and development process. The students should acquire the ability to use the presented development tools in their engineering practice.
Contents	The course provides an overall picture of the basic technologies in electrical multilayer ceramics currently used in innovative automotive sensors. With respect to efficient product development due to high demand on quality, complexity and cost in the field of automotive sensors, systematic development methods and quality management tools are discussed and extended in practices. Topics covered: Exhaust gas sensors for combustion engine management; Multilayer ceramic technology; Systematic product development methods; Quality management tools The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available at http://www.iwe.kit.edu
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Materials and Devices in Electrical Engineering**
Course code	**23211**
Associated Exercise	none
Lecturer/ Institute	Dr. A. Weber / IWE
Credit Points	3
Semester hours	2
Term	Bachelor/Master
Compulsory course	Bachelor/Master
Prerequisites	none
Objectives	The lecture provides fundamental knowledge about Materials and Devices applied in Electrical Engineering.
Brief description course	The lecture of "Materials and Devices in Electrical Engineering" concerns the fundamental ideas of the electrical materials. It contains the minimum subject matter which can be recommended to the studying of "Electrical Engineering".
Contents	Materials play a central role for the progress of technology and economy. Their applications determine the innovation degree of modern technologies like the information-, energy-, traffic-, manufacturing-, environmental and medical technology. Many innovations in electrical engineering could only be realized on the basis of new material and production engineering. Therefore the development of materials and their applications in systems become one of the key fields of the industrial technology in the 21st century with outstandingly high strategic meaning. The lecture of "Materials and Devices in Electrical Engineering" concerns the fundamental ideas of the electrical materials. Topics covered: Structure of Atoms and Solids, Electrical Conductors, Dielectric Materials, Magnetic Materials The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Copies of the slides are available at http://www.iwe.kit.edu/. Literature: William D. Callister, Materials Science and Engineering, John Wiley & Sons, Inc.,ISBN No. 0-471-32013-7
Language	English
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture

Course name	**Battery- and Fuel Cell Systems**
Course code	**23214**
Associated Exercise	none
Lecturer/ Institute	Dr. A. Weber / IWE
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Batteries and Fuel Cells
Objectives	The participants will gather the knowledge required for the technological development and economic evaluation of battery and fuel cell systems by means of selected examples.
Brief description course	In the lecture Battery- and Fuel Cell Systems, the topics of the first lecture (23207) will be deepened, current technology developments will be discussed and system-relevant aspects will be covered.
Contents	The various cell concepts, the design of stacks and the components required for systems are treated in detail for the most common low- and high-temperature fuel cells. This lecture especially emphasizes the electrical operating behaviour of systems. Here, the aspects of power, long-term stability and the loss mechanisms associated with degradation phenomena are discussed on the basis of own research projects. The treatment of systems for electrotraction focuses on the lithium-ion battery. Its operating behaviour, failure mechanisms, and the development status of high-energy batteries are presented. Knowledge on electrochemical characterization methods and modeling of batteries and fuel cells is furthered. The current topics and dates can be found at: http://www.iwe.kit.edu/ . The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Copies of the slides are available on http://www.iwe.kit.edu/ .
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Seminar Batteries and Fuel Cells**
Course code	**23215**
Associated Exercise	none
Lecturer/ Institute	Dr.-Ing. André Weber / IWE
Credit Points	3
Semester hours	2
Term	Bachelor/Master
Compulsory course	Bachelor/Master
Elective course	Elective course for all fields of specialisations
Prerequisites	none
Objectives	The student will learn how to deal with a scientific topic, to analyze literature, to summarize the published results and to present them in a talk.
Brief description course	This seminar is designed for students who are interested in a bachelor or master thesis in the field of fuel cells and batteries.
Contents	In the first part of the seminar fundamental knowledge about fuel cells and batteries will be provided. In the second part, the student has to analyze literature related to a scientific topic, which might be the topic of his/her bachelor / master thesis. The results of this literature study have to be summarized in a term paper and presented in a talk. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Copies of the slides are available on http://www.iwe.kit.edu/ .
Language	German
Examination	Term paper and talk (in German or English)
Formation of grade	Grades result from the quality of the term paper and the talk.
Course form	Seminar

Course name	**Electrical Engineering for Business Engineers, Part I**
Course code	**23223**
Associated Exercise	23225
Lecturer/ Institute	Dr. Wolfgang Menesklou / IWE
Credit Points	3
Semester hours	2
Term	Bachelor/Master
Compulsory course	Bachelor/Master
Prerequisites	none
Objectives	The student is supposed to develop an understanding for the basic terms of electrical engineering and should be able to carry out simple calculations of DC and AC circuits.
Brief description course	This course introduces undergraduate students of business engineering into the basics of electrical science and engineering.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. These are solved into additional (voluntary) tutorials.
Contents	DC: Electrical sources, resistance, circuits, Kirchhoff's law Fields: Electrical and magnetic fields, dielectrics, inductance AC: Complex calculus, RLC circuits, filters The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available at http://www.iwe.kit.edu Literature: G. Hagmann, Grundlagen der Elektrotechnik, Aula Verlag Wiebelsheim, 14. Auflage 2009
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office).
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises

Course name	**Electrical Engineering for Business Engineers, Part II**
Course code	**23224**
Lecturer/ Institute	Dr. Menesklou / IWE
Credit Points	5
Semester hours	3
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Electrical Engineering for Business Engineers, Part I [23223]
Objectives	The student is supposed to develop an understanding for the basic terms of electrical engineering.
Brief description course	This course introduces undergraduate students of business engineering into topics of advanced electrical engineering like electrical instrumentation, semiconductors, communication systems and electrical machines.
Brief description exercises	Within the lecture, assignments to the curriculum are discussed and are used for preparation to written examination.
Contents	Electrical instrumentation, Semiconductor Devices, Communication Engineering, Electrical Machines. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available at http://www.iwe.kit.edu
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office).
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises

Course name	**Sensors**
Course code	**23231**
Associated Exercise	none
Lecturer/ Institute	Dr. Menesklou / IWE
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basics in material science, and in electrical and electronics engineering.
Objectives	The student should acquire fundamental principles in material science and device technology of sensors to be able to apply materials and sensors from the viewpoint of an application or development engineer.
Brief description course	The course covers the most important features for understanding of sensors. In addition to the basic scientific understanding of sensor, the material aspects, the technical realization of components, and the application of the sensors in electrical circuits and systems are discussed.
Contents	Mechanical Sensors (strain gauges, piezoelectric sensors), Thermal Sensors, Optical Sensors, Magnetic sensors, Acoustic Sensors, Gas Sensors (Lambda Probes, Taguchi, Electronic Nose), Bio and Chemical Sensors. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available at http://www.iwe.kit.edu
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture

Course name	**Sensors and Actuators Laboratory**
Course code	**23232**
Lecturer/ Institute	Dr. W. Menesklou / IWE
Credit Points	6
Semester hours	4
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Sensors [23231]
Objectives	The student should acquire fundamental principles in material science and device technology of sensors and actors to be able to apply materials and sensors from the viewpoint of an application or development engineer.
Brief description course	In this course, the electrical properties of sensors and electronic components currently used in a broad range of technical applications are examined.
Contents	In groups of three, the students measure autonomously the relevant characteristics of materials, sensors and actuators. Insights may be gained into the fundamental physical mechanism and also the factors determining the design and development of components utilizing these materials. The students should acquire the capability to analyze and present experimental data, and should be able to discuss the technological and economical boundary conditions. Content: Impedance spectroscopy, Piezoelectric components, Temperature sensors (NTC, PTC), Exhaust gas sensors, Magnetic sensors, Intelligent shock absorber (adaptronic systems), Scientific presentation The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available at http://www.iwe.kit.edu
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Laboratory
General remarks	The number of participants is limited

Course name	**Seminar Sensors**
Course code	**23233**
Associated Exercise	none
Lecturer/ Institute	Dr. Menesklou / IWE
Credit Points	3
Semester hours	2
Term	Summer and winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Sensoren [23231]
Objectives	The student will learn how to deal with a scientific topic, to analyze literature, to summarize the published results and to present them in a talk.
Brief description course	This course is aimed to graduate students in electrical and business engineering. Students will be trained in acquisition, selection and classification of information in the field of sensors and actuators and in preparing reports and presenting their results.
Contents	The student has to analyze scientific literature related to sensors. The results of this literature study have to be summarized in a paper and presented in a talk. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Information about the course can be found online at http://www.iwe.kit.edu
Language	German
Examination	Oral, evaluation of written work and the talk
Formation of grade	Grades result from the quality of the term paper and the talk.
Course form	Seminar

Course name	**Laboratory: Batteries and Fuel Cells**
Course code	**23235**
Associated Exercise	none
Lecturer/ Institute	Dr.-Ing. André Weber / IWE
Credit Points	6
Semester hours	4
Term	Summer and winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Batteries and Fuel Cells [23207], Battery- and Fuel Cell Systems [23214]
Objectives	The students will learn how to design and apply testing modules and procedures to evaluate the performance of batteries and fuel cells.
Brief description course	In this lab course testing of batteries and fuel cells will be performed on the system, stack and single cell level. Different methods like CV-characteristics and impedance spectroscopy will be applied.
Contents	Topics covered: Testing of fuel cell stacks Testing of fuel cell systems Electrochemical characterization of single cells Electrochemical impedance spectroscopy Data evaluation and interpretation The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on http://www.iwe.kit.edu/.
Language	German
Examination	participation and records
Formation of grade	The grade is based on: oral examination at the beginning of each experiment, cooperation during the experiment, written records / laboratory notebook
Course form	laboratory course
General remarks	max. number of participants: 5 per semester

Course name	**Sensor systems (Integrated Sensor Actuator Systems)**
Course code	**23240**
Associated Exercise	none
Lecturer/ Institute	W. Wersing / IWE
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basics in material science, and in electrical and electronics engineering.
Objectives	The student should acquire fundamental principles in material science and device technology of piezoelectric sensor and actuator systems to be able to judge the innovation potential of such systems from the viewpoint of an application or development engineer.
Brief description course	Innovation oriented course integrated sensor and actuator systems. Essential points are the basics of piezoelectric and electrostrictive materials, measurement methods to characterize them, design and optimization of sensor and actuator structures, driving and control electronics for integrated sensor and actuator systems, and finally the application of these systems in different technical fields.

Contents

This lecture presents an introduction to the technology of modern integrated sensor and actuator systems and related piezoelectric materials. It illustrates important technical innovations achieved with the aid of this technology and demonstrates its potential for future innovations.

On the one hand, integrated sensor and actuator systems are generally defined as devices and systems functioning due to their combined sensor and actuator effect. On the other hand special devices are meant that function due to the integration of sensor or actuator structures into silicon chips.

At first the fundamentals of piezoelectricity and related phenomena as well as the crystallographic structure of piezoelectric materials are introduced

Measurement techniques to characterize piezoelectric materials and devices are the subject matter of a further section. The fact that we have to deal with the directionality of the response of piezoelectric materials and consequently with tensors, complicates engineering to some extent. However, on the other hand, it offers a great design potential for engineers in the development of piezoelectric devices. Because, today, the design of new devices is done by using computational tools, it is decisive for the engineer to have access to a complete set of the property coefficients (tensor components) of the materials applied. Therefore, methods to precisely determine dielectric, elastic, and piezoelectric coefficients are introduced here.

In order to achieve a sensor and actuator system of highest performance, it is essential not only to choose an optimally tailored piezoelectric material but also to select a suitable and optimally designed transducer structure. Therefore the lecture introduces the different basic structures of piezoelectric sensors and actuators and gives useful hints for a functional design. Particularly, transducer structures based on piezoelectric bulk materials, piezoelectric multilayer ceramics, and piezoelectric composites are discussed. In addition, piezoelectric transducers for ultrasonic motors as well as integrated piezoelectric thin films for micro electromechanical systems (MEMS) and bio sensors are presented.

A further section deals with the different driving and control techniques used for piezoelectric actuators. Piezoelectric actuators are usually classified according to three main driving principles. These are pulse driven actuators, resonance transducer actuators, and servo-controlled actuators. The latter are a typical example of an integrated sensor- and actuator system. With servo-controlled operation using suitable position sensors, nonlinear effects like hysteresis and drift are eliminated, and in this way the basis for repeatable positioning in the nanometer range is established.

In the last section of the lecture a broad selection of device applications is presented which reflects the huge spectrum of functionalities covered by piezoelectric sensor and actuator systems in our world today.

In addition problems to the subject-matter of the lecture are handed out. Detailed solutions of the problems are presented and discussed.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available at http://www.iwe.kit.edu; Literature: W. Heywang, K. Lubitz, W. Wersing (Eds.), Piezoelectricity Evolution and Future of a Technology, Springer, Berlin, 2009
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Seminar on Selected Chapters of Biomedical Engineering**
Course code	**23254**
Lecturer/ Institute	Dr. Seemann / IBT
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	Introduction in scientific working, presentation training
Brief description course	This course aims at training students towards treating topics in Biomedical Engineering self-employed and improving their presentation techniques. First an introduction in presentation techniques and feedback strategies is given, than a test presentation is given in order to try out these techniques. Finally the students select a biomedical engineering topic to present.
Contents	Lectures on various topics of Biomedical Engineering The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Linear Electronic Networks**
Course code	**23256**
Associated Exercise	23617
Lecturer/ Institute	Prof. Dössel / IBT
Credit Points	6 + 1,5
Semester hours	4 + 1
Term	Winter term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	none
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	This course provides fundamental knowledge of linear electronic circuits. Methods to analyse complex DC and AC circuits are taught.
Brief description exercises	To accompany the lecture exercise problems and the corresponding solutions will be given out and discussed during lecture hall exercises. Furthermore tutorials in small study groups are held to deepen the understanding of the curriculum and methods taught. In addition there is a project, where the students have to solve a larger problem in a team.
Contents	Methods to analyse complex linear electric circuits Definitions U, I, R, L, C, independent sources, dependent sources Kirchhoff's laws, node-voltage method, mesh-current method Thevenin and Norton equivalents, Delta to Wye transformation, maximum power operational amplifier, inverting amplifier, summing amplifier, emitter follower, noninverting amplifier, difference amplifier sinusoidal currents, differential equations for L- and C-circuits, complex numbers, complex RLC-circuits, impedance, complex power, maximum power transfer bridge circuits, Wheatsone, Maxwell-Wien, Wien bridge series and parallel resonance two-port circuits, Z, Y, A-matrix, impedance transformation, phasor-diagrams, Bode diagrams, high pass, low pass, band pass operational amplifier and RLC-circuits transformer, mutual inductance, transformer equations, equivalent circuits three-phase-circuits, power calculations in balanced circuits The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Lecture notes
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination and the project
Course form	Lecture, Exercises, and Tutorials
General remarks	The course comprises of the interleaved lecture blocks, exercises, and tutorials. Current information can be found on the ITIV (http://www.ibt.kit.edu/) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Medical Imaging Techniques I**
Course code	**23261**
Associated Exercise	/
Lecturer/ Institute	Prof. Dössel / IBT
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	23275
Objectives	Comprehensive understanding of all methods of medical imaging based on ionizing radiation
Brief description course	This course teaches students to understand theoretical aspects and engineering of x-ray imaging systems (incl. Computed Tomography) and imaging methods of Nuclear Medicine (SPECT and PET).
Brief description exercises	/
Contents	X-ray Physics and technique of X-ray imaging Digital radiography, x-ray image intensifier, flat x-ray detectors Theory of imaging systems, Modulation-Transfer-Function and Detective Quantum Efficency Computer Tomography CT Ionizing radiation, dosimetry and radiation protection SPECT and PET The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Book: Bildgebende Verfahren in der Medizin, Olaf Dössel, Springer Verlag
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture
General remarks	Current information can be found on the ITIV (http://www.ibt.kit.edu/) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Medical Imaging Techniques II**
Course code	**23262**
Lecturer/ Institute	Prof. Dössel / IBT
Credit Points	3
Semester hours	2
Term	Sommer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	23270, Fourier Transform
Objectives	Comprehensive understanding of all methods of medical imaging without ionizing radiation
Brief description course	This course teaches students to understand theoretical aspects and techniques of ultrasound-, Magnetic Resonance- and some unconventional imaging systems.
Brief description exercises	/
Contents	Ultrasonic imaging Thermography Optical tomography Impedance tomography Imaging of bioelectric sources Endoscopy Magnetic Resonance Tomography Multimodality imaging Molecular Imaging The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Book: Bildgebende Verfahren in der Medizin, Olaf Dössel, Springer Verlag
Language	Deutsch
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture
General remarks	Current information can be found on the ITIV (http://www.ibt.kit.edu/) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Electromagnetics and Numerical Calculation of Fields**
Course code	**23263**
Associated Exercise	/
Lecturer/ Institute	Prof. Dössel / IBT
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fundamentals of Electromagnetic Field Theory
Objectives	This course is an introduction to modern methods of numerical field calculation
Brief description course	The course starts with a revision of Maxwell equations and the most important methods of analytical field calculation. Then the most important methods of numerical field calculation are presented.
Brief description exercises	/
Contents	Maxwell's equations, materials equations, boundary conditions, fields in ferroelectric and ferromagnetic materials electric potentials, electric dipole, Coulomb integral, Laplace and Poisson's equation, separation of variables in cartesian, cylindrical and spherical coordinates Dirichlet Problem, Neumann Problem, Greens function, Field energy density and Poynting vector, electrostatic field energy, coefficients of capacitance vector potential, Coulomb gauge, Biot-Savart-law magnetic field energy, coefficients of inductance magnetic flux and coefficients of mutual inductance, fields problems in steady electric currents, law of induction, displacement current general wave equation for E and H, Helmholtz equation skin effect, penetration depth, eddy currents retarded potentials, Coulomb integral with retarded potentials wave equation for φ and A, Lorentz gauge, plane waves Hertzian dipole, near field solution, far field solution transmission lines, fields in coaxial transmission lines waveguides, TM-waves, TE-waves finite difference method FDM finite difference - time domain FDTD, Yee´s algorithm finite difference - frequency domain finite integration method FIM finite element method FEM boundary element method BEM solving large systems of linear equations basic rules for good numerical field calculation The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Recommendation of several books, Figures of the lecture
Language	English

Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture
General remarks	Current information can be found on the ITIV (http://www.ibt.kit.edu/) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Bioelectric Signals and Fields**
Course code	**23264**
Lecturer/ Institute	Dr. Seemann / IBT
Credit Points	3
Semester hours	2
Term	Sommer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	23281
Objectives	Bioelectricity and mathematical modelling of the underlying processes
Brief description course	The students learn how bioelectrical signals are generated in the human body and how these signals can be measured and interpreted. The content is explained both on the biological level and based mathematical modelling.
Contents	Cell membrane and ion channels Cell physiology Conduction of action potentials Numerical field calculation in the human body Measurement of bioelectrical signals Electrocardiography and electrography, electromyography and -neurography Electroencephalogram, evoked potentials and magnetic measurement techniques Imaging of bioelectrical sources The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Bioelectromagnetism: J. Malmivuo
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Entrepreneural thinking for engineers**
Course code	**23265**
Lecturer/ Institute	Prof. Bolz / IBT
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Key Qualification
Brief description course	This lecture provides basics of entrepreneural thinking and acting. It will help young engineers to get prepared for their professional life in industry.
Contents	Students of our technical university, who think that high technical skills are sufficient to get a „good job“, that their income appear out of the nowhere and that leadership is only important in their soccer club, should not attend this lecture. Students who are afraid that there might be another “secret” world outside engineering that is also important for the economical success should risk a look beyond one’s own nose. The lecturer is a professor of the University of Karlsruhe as well as a successful entrepreneur. He tries to demonstrate economical, planning as well as emotional aspects of leading a company. This knowledge is part of the key qualification of successful engineers. He will not only present theoretical explanations, but give also practical examples and exercises. Playing different situations the students will get a feeling of the important issues. It might be possible that some students get the desire to start their own company. This is one of the objectives of the lecture. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Will be provided during the lecture
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the IBT (http://www.ibt.kit.edu/) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Biomedical Measurement Techniques I**
Course code	**23269**
Lecturer/ Institute	Prof. Bolz / IBT
Credit Points	4,5
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	23281, 23261
Brief description course	This course teaches students to understand physiological systems and biomedical measuring techniques. It provides knowledge of how physiological parameters can be measured applying electrical engineering measuring techniques to the human body.
Contents	Origin of Biopotentials: Anatomy and Physiology of the Nerv Cell and the Nervous System, Resting State of the Cell, Electrical Activity of Excitable Cells, Recording Technique of Resting and Action Potentials. Biopotential Electrodes: Electrode-Electrolyte-Interface, Polarisation, Polarizable and Nonpolarizable Electrodes, Electrode Behaviour and Circuit Models, Electrode Skin Interface. Biopotential Amplifiers: - Basic Requirements, Differential Amplifier, Biopotential Pre-Amplifier. Interference: - Interference in the Lead System, External Interference, Galvanic Coupled Interference, Capacitive Coupled Interference, Inductive Coupled Interference, Measuring Techniques of Electric and Magnetic Fields, Methodes of Interference Reduction. Biopotentials of Nervesystem and Muscles: Anatomy and Function, Electroneurogram (ENG), Electromyogram (EMG), Nerve Conduction Velocity, Diagnosis, Recording-Technique. Biopotentials of the Brain: Anatomy and Function of the Central Nervous System. Electro Corticogram (ECoG), Electroencephalogram (EEG), Recording-Technique, Diagnosis. Electrocardiogram (ECG): Anatomy and Function of the Heart, Ventricular Cell, Ventricular Activation, Body Surface Potentials. Electrical Safety: Physiological Effects of Electricity, Shock-Hazards, Electrical Safety Codes and Standards, Approaches to Protection against Shocks, Testing of Electric Systems. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Bolz, Urbaszek: Technik in der Kardiologie (Springer 2002)
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the IBT (http://www.ibt.kit.edu/) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Biomedical Measurement Techniques II**
Course code	**23270**
Lecturer/ Institute	Prof. Bolz / IBT
Credit Points	4,5
Semester hours	3
Term	Sommer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	23261, 23263, 23282
Brief description course	This course extends the knowledge acquired from course 23275. It teaches students to understand physiological systems and biomedical measuring techniques. It provides knowledge of how physiological parameters can be measured applying electrical engineering measuring techniques to the human body.
Contents	Blood Pressure Measurement: Physical and Physiological Fundamentals, Analysis of Blood-Pressure Waveforms. Non-invasive Methods: Korotkow-and Oscillation Method. Invasive Methods: Dynamic Properties of Measurement Systems, Transfer-Function, Measurement of System Response, Effect of System Parameters on Response, Effects on Pressure Measurements, Catheter-tip Transducers. Blood Flow Measurement: Physical and Physiological Fundamentals, Electromagnetic Flowmeter: DC-, AC-Excitation, Ultrasonic Flowmeters: Transit-Time-, Doppler-Shift Flowmeters. Measurement of Cardiac Output: Physical and Physiological Fundamentals, Fick Method, Indicator-Dilution Method, Electric Impedance Pletysmography, Diagnosis. Electrostimulation: Physical and Physiological Fundamentals: DC-, Low - and Middle Frequency Currents, Local and System Compatibility, Physiological Thresholds, Voltage Source, Current Source, Analysis of Different Current Shapes. Heart-Defibrillation: Electrophysical Fundamentals, Normal and Abnormal Cardiac Rhythms, Technical Realization: External and Implantable Defibrillators - Semi-Automatic and Automatic Systems, Safety Considerations. Heart-Pacemaker: Electrophysical Fundamentals, Indications, Single-Chamber-, Dual-Chamber-Systems: V00...DDDR, Pacemaker Technology: Electrodes, Case, Energy, Electronics. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Bolz, Urbaszek: Technik in der Kardiologie (Springer 2002)
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the IBT (http://www.ibt.kit.edu/) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Laboratory Biomedical Engineering**
Course code	**23276**
Lecturer/ Institute	Prof. Bolz / IBT
Credit Points	6
Semester hours	4
Term	Sommer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	23275
Brief description exercises	This course teaches practical basics of biomedical measuring technique. It provides knowledge of understanding practical problems in biomedical engineering and of using modern engineering techniques and tools.
Contents	Biomedical signal processing Invasive measurement of blood pressure Non-invasive measurement of blood pressure Electrocardiography Amplifier techniques for bioelectric signals Impedance measurement in human tissue Electrostimulation Electromyography and power of muscle contraction Haematology The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Material is provided in the internet
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Laboratory
General remarks	Current information can be found on the IBT (http://www.ibt.kit.edu/) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Nuclear Medicine and Measuring Techniques I**
Course code	**23289**
Lecturer/ Institute	Prof. Doerfel, Prof. Maul/ IBT
Credit Points	1,5
Semester hours	1
Term	Winter term
Bachelor/Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	The course presents the connection between clinical problems and their metrological solution on the basis of nuclear medical examples from function diagnosis and therapy.
Brief description course	The basic concept of the course is the presentation of metrological procedures illustrated by nuclear medical examples by both lecturers. Basic metrological and nuclear medical concepts are communicated. The course includes an excursion to the Research Centre Karlsruhe with a visit of the whole body counter in order to measure the natural radioactivity in the body of the students.
Contents	- Virtual tour through a nuclear medical establishment and introduction into basic concepts of nuclear physics - Physical and biological interactions of ionizing radiation - Design of nuclear medical detector systems using the example of Iodine metabolism - Biokinetics of radioactive materials for internal dosimetry and determination of kidney clearance - Impact of statistical uncertainties and biological fluctuations on the analytical results - Quality control: metrological and medical standardization of analytical methods Epidemiological data and models for cost-benefit assessment. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Commented slides
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the IBT (http://www.ibt.kit.edu/) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Nuclear Medicine and Measuring Techniques II**
Course code	**23290**
Lecturer/ Institute	Prof. Maul, Prof. Doerfel / IBT
Credit Points	01. Mai
Semester hours	1
Term	Summer term
Bachelor/Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	The course deals with the measuring techniques of scintigraphy, SPECT and PET using appropriate medical examples. Nuclear medical concepts are communicated as well as basic clinical terms. In this context important diseases are addressed such as coronary heart and cancer diseases.
Brief description course	The winter term course „Nuclear Medicine and Measuring Techniques I“ is not required for this course. On the other hand there is only small overlapping of both courses. The summer term course mainly addresses the qualitative and quantitative nuclear medical imaging procedures. Other imaging procedures of nuclear medicine are also considered. The lectures are presented by both lecturers together in order to emphasise the various links in between nuclear medicine and measuring techniques. The course includes an excursion to the Nuclear Medical Clinic of the Karlsruhe Municipal Clinical Centre.
Contents	- Overview of scintigraghic methods for medical examination and introduction into medical imaging - Planar and whole body scintigraphy using the example of visualisation of bone remodelling (skeletal szintigraphy) - Tomography (SPECT) for visualisation of myocardial blood flow - Metrological conditions for quantification of myocardial scintigraphy for prognostic assessment - PET and PET/CT for diagnostics of cancer dimension - Quantitative assessment of diagnostic radiopharmaceuticals *in vivo* for evaluation of malign disease biology - Quantitative intercomparisons of regional metabolism of healthy and diseased subjects by means of FDG brain PET The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Commented slides
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the IBT (http://www.ibt.kit.edu/) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Electrical Machines and Power Electronics**
Course code	**23307**
Associated Exercise	23309
Lecturer/ Institute	Prof. Braun / ETI
Credit Points	6
Semester hours	2 + 2
Term	Winter term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	Basic study knowledge of mathematics, Linear electrical networks
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	Drive technology and power electronics fundamental lecture. At first the mode of operation and operation behaviour of the most important electrical drives will be explained. Followed by description of function and operation behaviour of the most important power converters. Examples of typical applications for electrical drives and power converters should increase the understanding.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises

Contents

Lecture

This lecture presents an introduction to the fundamentals of electrical drive systems and power electronics. The mode of operation, operation behaviour, control and typical applications of the most important electrical drives and power converters will be imparted.

At first the requirements and components of a drive system will presented in the lecture. Typical speed-torque-characteristics of the driven machine and the electrical drive will be shown. After that physical basics of electromagnetism and induction on which the function of most of the electrical drives depends will be explained.

After the basics the most important electrical drives will be discussed in detail: DC-machine, stepping motor, synchronous machine and induction machine. The basic configuration and mode of operation will be explained and the characteristic equations will be deduced. Additionally different variants of the machines and their typical applications will be shown.

A special kind of an electrical machine is the transformer. Configuration, mode of operation, operation behaviour of AC-transformers, three-phase transformers and autotransformers will be presented.

The second part deals with power electronics. At first characteristics, operation behaviour and common use of the most important power semiconductors will be described. After that fundamental power converter circuits will discussed in detail. To begin with line-commutated converters followed by self-commutated converters.

The final chapter about drive systems consisting o driven machine, electrical drive, power converter, control and measured-value acquisition should increase the understanding of the complete system. Furthermore typical applications of power electronics in energy transmission systems will be presented.

Exercises

	To accompany the lecture material, assignments and the corresponding solutions will be given out and discussed during lecture hall exercises. Furthermore tutorials in small study groups will be held to deepen the understanding of the curriculum and methods taught. Furthermore computer exercises are offered in which digital circuits and their pattern of behaviour will be modelled and simulated with the help of the program LogicWorks. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The lecture notes are available at the secretary's office of the ETI. Assignments will be given out and are available online.
Language	German
Examination	Written (see current document "Studienplan" and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the webpage of the ETI (www.eti.uni-karlsruhe.de).

Course name	**Practical Aspects of Electrical Drives**
Course code	**23311**
Associated Exercise	23313
Lecturer/ Institute	Prof. Braun / ETI
Credit Points	4,5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Lecture 23307 - Electrical Machines and Power Electronics
Objectives	The goal is to relay practical aspects on the field of electrical drives.
Brief description course	This course is an introduction to electrical drives and electrical drive systems.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.
Contents	Lecture electrical drives and inverters: d. c. motor induction motor synchronous motor linear motor inverter topologies co-operation of electrical drive and working unit: characteristics of torque coupling of motor and working unit operating points starting procedures and braking torque of inertia basic principles of electrical drives rated values operation mode environmental conditions heating overload protection noise emission circle diagram of the induction motor equivalent circuit of the induction motor typical drive systems dimensioning of electrical drives speed control inverter-fed drives Exercises motion and torque of inertia modelling of temperature circle diagram of the induction motor project planing of drive systems
Lecture notes	lecture notes available at the institute
Language	German
Examination	Written (see current document “Studienplan” and notice of the examination office ETIT).

Formation of grade	Grades result from the written examination
Course form	Lecture, Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the ETI (www.eti.uni-karlsruhe.de) webpage.

Course name	**Control of Electrical Drives**
Course code	**23312**
Associated Exercise	23314
Lecturer/ Institute	Prof. Dr.-Ing. M. Braun / ETI
Credit Points	6
Semester hours	3 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	knowledge from Electrical Machines and Power Electronics
Objectives	The goal is to relay the fundamental methods of the closed loop control of electrical drives.
Brief description course	Quality intensification and energy saving are achieved by fast, precise and motor adapted control of electric energy. In this lecture the closed loop control methods are presented, which allow the high dynamical control of position, speed and torque. The application of this methods and their impact on system dynamics are discussed on drive solutions with dc machines, synchronous and asynchronous machines.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.
Contents	Lecture This lecture starts with the definition of the function of drive system. The modelling of the mechanical subsystem is the basis for the design of the closed loop speed control circuit. The modelling of the electrical subsystem at the dc machine enables the design of the current controller. Hereby the fundamental layout of the cascade control structure with subordinate current and the superimposed speed controller is shown. After the introduction into the description of three phase systems by space vectors the current control in a rotating coordinate system is described. In a further chapter the closed loop control methods on basis of the dynamical description of the permanent magnet synchronous machine are explained. Controlling asynchronous machines is in the focus of this lecture. Different kinds of open loop control methods are presented. By means of the model of the asynchronous machine in a rotor flux orientated coordinate system the derivation of various methods for closed loop control of the aysnchronous machine is carried out. A one day excursion to a manufacturer or a user of electric drive systems shall deepen the connection to the industrial practice. Exercises To accompany the lecture material, assignments will be given out and discussed during lecture hall exercises. Practical demonstations of electrical drives systems complete this exercise. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The lecture notes are available at the secretary's office of the ETI. Assignments will be given out and are available online.

Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the webpage of the ETI (www.eti.uni-karlsruhe.de).

Course name	**Seminar Neue Komponenten und Systeme der Leistungselektronik**
Course code	**23317**
Lecturer/ Institute	Prof. Dr.-Ing. M. Braun / ETI
Credit Points	4,5
Semester hours	3
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	The participants shall learn to work out the state of technology by study of literature and contribute own ideas to the topic. They also shall get known to presentation techniques and practise successful behaviour during lecture and discussion
Brief description course	The participants of the seminar are to inquest independently up to date topics of science and research. Besides the investigation, the selection of relevant results and the presentation in front of an audience of specialists are main parts of the seminar.
Contents	The focus is on new components and systems of power electronics. The precise topic is newly defined every semester. For example past seminars had following topics: - Hybrid drive systems for cars - Configuration and characteristics of modern high performance semiconductors - Storage of electrical energy - Converters in energy transmission systems The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	A part of the literature will be presented at the beginning of the course. Literature research by the participants is part of the seminar
Language	German
Examination	Periodic meetings for checking the progress, final presentation
Formation of grade	The grade is set by content and form of the final presentation. The criteria are the clarity of structure of the content, convincing by word and image and the behaviour during discussion on questions of the audience
Course form	Seminar
General remarks	Current information can be found on the ETI webpage (www.eti.uni-karlsruhe.de).

Course name	**Seminar Leistungselektronik in Systemen der regenerativen Energieerzeugung**
Course code	**23318**
Lecturer/ Institute	Prof. Dr.-Ing. M. Braun / ETI
Credit Points	04. Mai
Semester hours	3
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	The participants shall- learn to work out the state of technology by research and study of literature- contribute own ideas to the topic, e.g. by evaluation of different variants- get known to presentation techniques- practise successful behaviour during lecture and discussion
Brief description course	The participants of the seminar are to inquest independently up to date topics of science and research. Besides the investigation, the selection of relevant results and the presentation in front of an audience of specialists are main parts of the seminar.
Contents	The focus is on power electronics in systems of regenerative energy production. The precise topic is newly defined every semester. For example past seminars had following topics: - Off shore windparks: projects, technology, grid connection - Winning electrical energy from the ocean - Solar plants - Wind power plants: modern designs and grid connection The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	A part of the literature will be presented at the beginning of the course. Literature research by the participants is part of the seminar
Language	German
Examination	Periodic meetings for checking the progress, final presentation
Formation of grade	The grade is set by content and form of the final presentation. The criteria are: - clarity of structure of the content- convincing by word and image- behaviour during discussion on questions of the audience
Course form	Seminar
General remarks	Current information can be found on the ETI webpage (www.eti.uni-karlsruhe.de).

Course name	**High Power Converters**
Course code	**23319**
Associated Exercise	none
Lecturer/ Institute	Prof. Braun / ETI
Credit Points	3
Semester hours	2 + 0
Term	winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basics of electrical Engineering
Objectives	Function and performance of power electronic circuits
Brief description course	Specialized lecture. The main topic is the treatment of mains controlled converters with diodes and thyristors: AC-DC converter, cycloconverter and phase controlled AC converter. Further, the application aspects and the protection of power semiconductors are treated.
Brief description exercises	No Exercise
Contents	Lecture The content of the lecture are power electronic circuits using diodes and thyristors. The circuits are presented and analyzed. Firstly, the basic performance under ideal conditions is given. Secondly, the influence of real conditions is added. Following topics are trated in detail: Mains commutated Power converters under idealized conditions, transformers for power electronic power circuits, mains commutated power converters under real conditions, 12-pulse power converters, cycloconverter, High Voltage DC Transmission systems, 1 phase and 3 phase ac voltage controller, influence on the mains power quality, Power semiconductors for mains commutated converters, snubbers and protection. The content of the lecture may be changed without prior notice according to actual requirements. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Printed lecture material is available at secretary of ETI. Proposals for literature are listed there, for example: Heumann;K.:Grundlagen der Leistungselektronik, Teubner Studienbücher Elektrotechnik, B.G. Teubner Stuttgart 1996
Language	German
Examination	Oral (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the examination.
Course form	Lecture
General remarks	The lecture is considered as first part of the topic Power Electronics.

Course name	**Power electronics**
Course code	**23320**
Associated Exercise	none
Lecturer/ Institute	Prof. Braun / ETI
Credit Points	3
Semester hours	2 + 0
Term	winter term
Bachelor/ Master	Master
Elective course	Master
Prerequisites	Basics of Electrical Engineering
Objectives	Function and performance of power electronic circuits and components
Brief description course	Specialized lecture. The main topic is the treatment of self controlled converters with transistors and fully gate controlled thyristors (“Inverters”). Further, the application aspects and the protection of power semiconductors are treated.
Brief description exercises	No Exercise
Contents	Lecture The content of the lecture are power electronic circuits using transistors and fully gate controlled thyristors. The circuitry, control and function are presented and analyzed in detail. At first, the basic performance of self controlled circuits under idealized conditions are given, using the DC-chopper as example. After that, inverter circuits for three phase applications will be introduced and analyzed. The discussion of current and voltage stress of the power semiconductors enables the calculation of the performance and the design of inverters. Following topics are treated in detail:DC Chopper, boost-converter, 1 Phase AC bridge inverter, 3 Phase AC Bridge inverter, square wave control, subharmonic ontrol, space vector control, Multilevel inverters, soft switching inverters, resonant power converters, force commutated circuits, current and voltage stress of the power semiconductors, protection The content of the lecture may be changed without prior notice according to actual requirements. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Printed lecture material is available at secretary of ETI. Literature: Jenni,F.;Wüest, D.:Steuerverfahren für selbstgeführte Stromrichter. Teubner Verlag Stuttgart 1995, and: Ulrich, N. et al.:Applikationshandbuch IGBT-und MOSFET-Leistungsmodule, Verlag ISLE 1998, SEMIKRON 1998
Language	German
Examination	Oral (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the examination.
Course form	Lecture
General remarks	The lecture is considered as second part of the topic Power Electronics.

Course name	**Inductive Elements of Power Electronics**
Course code	**23326**
Lecturer/ Institute	Clos, Gerhard
Credit Points	1,5
Semester hours	1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Lecture 23307 - Electrical Machines and Power Electronics
Objectives	Knowledge about inductive elements of power electronics
Brief description course	Characteristics of inductive elements are presented in the lecture.
Contents	Lecture fundamental terms of electromagnetism mmf, flux and flux linkage law of induction system equations equivalent circuit calculation of inductance main- and leakage flux main- and leakage inductance Rogowski-factor steady-state operation load characteristic efficiency dynamic responce inrush short circuit force assembly core materials core designs three-phase transformers Y-connection delta connection The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	lecture notes available at the institute
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the ETI (www.eti.uni-karlsruhe.de) webpage.

Course name	**Industrial circuitry**
Course code	**23327**
Lecturer/ Institute	Clos, Gerhard
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Lecture 23307 - Electrical Machines and Power Electronics
Objectives	Knowledge about industrial circuitry
Brief description course	The lector describes the attributes of electrical devices and the procedure in industrial circuitry.
Contents	Steps in circuit design assignment of tasks conception wiring diagram design of a printed circuit board dimensioning of the components mechanical layout modularity connections heat dissipation heating sources and sinks thermal equivalent circuit diagram thermal capacity puls- and periodic stress cooling elements passive elements resistors capacitors inductors discrete semiconductors diodes transistors integrated semiconductors operation amplifiers logic circuits special circuits A/D converters D/A converters switch controllers The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	lecture notes available at the institute
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the ETI (www.eti.uni-karlsruhe.de) webpage.

Course name	**DC-Machine**
Course code	**23328**
Lecturer/ Institute	Clos, Gerhard
Credit Points	1,5
Semester hours	1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Lecture 23307 - Electrical Machines and Power Electronics
Objectives	Knowledge about the design and function of the DC-machine
Brief description course	Characteristics of the DC-machine are presented in the lecture.
Contents	Lecture assembly of the dc-machine main pole, excitation- and compensating winding commutating pole armature winding, lap- and wave winding brushgear unit fundamental operation of separately excited machine electric loading scheme system equations voltage- and torque generation voltage between segments calculation of inductance electric load and M.m.f curve main- and mutuel inductance air gap induction and armature reaction leakage inductance commutation commutation process armature quadrature-axis field and commutating pole field reactance voltage of commutation steady-state operation load characteristic operating range speed control field weakening four-quadrant operation instability dynamic responce structure diagram and differential equation oscillatory characteristics sudden voltage change and load step special series-wound dc-machine dc-generator compound excitation
Lecture notes	lecture notes available at the institute
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination

Course form	Lecture

Course name	**converter control technique**
Course code	**23330**
Lecturer/ Institute	Clos, Gerhard
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Lecture 23307 - Electrical Machines and Power Electronics
Objectives	Knowledge about analogue and digital principles for controlling converters
Brief description course	The lecture presents several controllers for converters. The theoretical aspects are described as well as the practical implementation is described.
Contents	Lecture fundamental terms of electromagnetism mmf, flux and flux linkage law of induction system equations equivalent circuit calculation of inductance main- and leakage flux main- and leakage inductance Rogowski-factor steady-state operation load characteristic efficiency dynamic responce inrush short circuit force The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	Oral (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the ETI (www.eti.uni-karlsruhe.de) webpage.

Course name	**Laboratory Electrical Drives and Power Electronics**
Course code	**23331**
Lecturer/ Institute	Dr.-Ing. K.-P. Becker / ETI
Credit Points	6
Semester hours	4
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Energietechnisches Praktikum
Objectives	The goal is the practical use of modern drives and power electronics.
Brief description course	Laboratory for sophisticated students with the focus on electrical drives and power converter technology.
Contents	Laboratory The laboratory leeds to practical knowledge on applications with electrical drives and power electronics in the following 8 experiments: Field orientated control of induction machines Permanent magnet synchronous machine Space vector transformation and current control with the digital signal processor Power semiconductor Speed-controlled dc-machine drive in four-quadrant operation line commutated converter circle diagram of the induction machine The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Material for this laboratory is available on the ETI homepage (www.eti.uni-karlsruhe.de).
Language	German
Examination	An oral examination will take place for every experiment (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	The final grades result from the arithmetic mean of the 8 grades from every experiment.
Course form	Laboratory
General remarks	Current information can be found on the ETI webpage (www.eti.uni-karlsruhe.de).

Course name	**Workshop „Circuit Design in Power Electronics“**
Course code	**23343**
Lecturer/ Institute	Dr. Clos / ETI
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Module „Electrical Machines and Power Electronics“
Objectives	The goal is to relay practical abilities in circuit design.
Brief description course	The students design and build up a printed circuit boards device by themselves. The intend is a step by step development of a working device by every participant. The students are coached by tutors for five afternoons to accomplish every necessary step.
Contents	This workshop shall prepare every student for his upcoming bachelor thesis. The student should learn to design and build up a electric device autonomously. In a first session, an overview about the necessary steps is given. The requirements on the device are defined and possible hardware resources are announced. Further, a software for computer aided circuit development will be presented and workplaces are assigned to the students in this session. The students develop their circuit and calculate the parameters of the chosen components in the following two afternoons supported by tutors. A printed circuit board will be manufactured by the computer implementation of the wiring scheme. The students assemble this boards and bring them into service. They measure the working parameters and compose a short documentation. The device and the measured data are presented in the last lesson. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Script of the module „Electrical Machines and Power Electronics“
Language	German
Examination	Function of the designed device.
Formation of grade	The grade is deduced by the fulfilment of the required specifications.
Course form	One lecture session and 7 afternoons of working autonomously.
General remarks	The number of participants is limited as every student needs his own workplace.

Course name	**System Analysis and Dynamic Operation of Three-Phase-Machine**
Course code	**23344**
Lecturer/ Institute	Dr. Becker / ETI
Credit Points	6
Semester hours	4
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic study knowledge of mathematics
Objectives	Methodical approach for the mathematical description of electrical machines with rotating magnetic field as a necessity for understanding the stationary operation as well as for the realization of highly dynamic drive systems.
Brief description course	Starting with the magnetic coupling of the two-coil-model the self-inductance and mutual inductance of a three-phase winding are calculated and the voltage equation system for the induction machine as well as for the synchronous machine are deduced. The inductance matrix, describing the coupling of the 6 winding strings to each other, is fully occupied and, furthermore, for the stator-rotor coupling time-variant. Therefore the voltage equation system is transformed with a unitary algorithm to the so called "space-vector" form which simplifies the system description dramatically. This is then the starting basis for the investigation of following themes: Steady-state operation by feeding with a symmetrical sinusoidal voltage supply as well as with a symmetrical non-sinusoidal supply and with a sinusoidal but unsymmetrical supply, too, dynamic behavior, explanation of the control structure as necessity for a highly dynamic drive with so called "field orientated control". The learned modeling is the essential scientific base for the (open and closed loop) control of precise, robust
Brief description exercises	No exercises
Contents	0. Introduction Mechanical construction – design types, assets and drawbacks, derivation of mutual inductance, calculation of torque. 1. Inductance of the air-gap field General calculation of mutual inductance with a Two-Coil-Model with current density pulses. Example of use: Resolver. 2. Windings in machines with rotating magnetic field Design of distributed windings and explanation of specific characterization factors. Construction of the air-gap field curve from the zone-plan and mathematical description with Fourier series. 3. System equations of the induction machine with slip ring rotor (ASM-SL) in the stator-orientated reference system with matrix-notation. 4. Power-invariant transformation In general and specific for the ASM-SL with following goal: Replacement of the 3 real equations for both stator and rotor by two complex equations (description with so called "space-vectors") with the following benefits:

	Conversion of the fully occupied and furthermore for the stator-rotor coupling also time-variant 3x3 inductance-matrices to time-invariant diagonal matrices. Additionally: Conversion of the rotor winding number to the value of the stator and description in any rotating reference system. 5. Voltage equation system in the transformed form Physical exemplification of “space vectors”, special case of the symmetrical and sinusoidal voltage system, inverse transformation , general calculation of the torque with “space vectors”. 6. Influence of the selected reference system stator-orientated, rotor-orientated and flux-orientated. 7. Steady-state operation of the ASM-SL at a symmetrical sinusoidal supply derivation of the equivalent circuit and the phase vector diagram. 8. Calculation of string values for delta- and star-connection, with and without neutral point connection. 9. Space vectors for the supply with a symmetrical non-sinusoidal voltage system Example of use: Two point converter with three output legs. 10. Steady-state operation of the ASM-SL at a symmetrical non-sinusoidal three-phase voltage supply. Equivalent circuit for harmonics, generalization of the slip definition, influence to the torque. 11. Steady-state operation of the ASM-SL at an unsymmetrical sinusoidal supply Symmetrical components, equivalent circuits, influence to torque and machine losses, generalized formula of Kloss. Examples of use: Single phase motor, interruption of a stator string. 12. Dynamic structure of the ASM Feeding with voltage- and current-system, selection of the reference system, field-orientated operation, decoupling. 13. Synchronous machine (SM) design types. 14. System equations of the magnetic unsymmetrical electrically excited SM with orthogonal damper winding Calculation of the mutual inductance. 15. SM in space vector description Calculation of the torque.
Lecture notes	Blackboard notes during lectures. Supplementary sheets are distributed during lectures. Math-Cad examples (on institute computers available). Amendatory: Späth, H.: Elektrische Maschinen, Springer Späth, H.: Steuerverfahren für Drehstrommaschinen, Springer
Language	German
Examination	Oral (date negotiable).
Formation of grade	Grades result from the oral examination
Course form	Lecture with „MathCad“ examples
General remarks	Current information can be found on the webpage of the ETI (www.eti.uni-karlsruhe.de).

Course name	**Workshop „Microcontrollers in Power Electronics“**
Course code	**23345**
Lecturer/ Institute	Dr. Clos / ETI
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Module „Electrical Machines and Power Electronics“, Basics of the programming language C
Objectives Brief description course	The purpose is to get the ability of programming a microcontroller autonomously. The students learn about the specialities of programming a microcontroller. They are supplied with a microcontroller controlled buck-boost-inverter, a workplace with a computer and hardware for programming the microcontroller. Until the end of the workshop, they should write a program for the microcontroller to drive the inverter and to provide a regulated output voltage.
Contents	In this workshop, the students are supplied with a buck-boost converter with a microcontroller. They program the microcontroller to regulate the output voltage from the converter until the end of the module. In the first lesson, the special attributes of the C programming language for microcontrollers are presented. These are most notably the following topics -the ability for real time computation -the limited computing power -the defined precision for calculations -registers for configuring integrated special hardware Information about the converter hardware and about the requested software functions are provided. Further, workplaces and necessary programming hardware are assigned to the students in this session. The students learn to program the microcontroller with assistance of tutors in the following afternoons. They make the following steps autonomously: -programming of a sequential control chain -configuring of the measured value acquisitioning -programming of the PWM modulator -programming of a cascade control for constant output voltage The results and measured output voltage characteristics are presented by the students in the last lesson. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Materials are provided in the first lesson
Language	German
Examination	Function of the microcontroller program.
Formation of grade	The grade is deduced by the fulfilment of the required software specifications.
Course form	Two lecture sessions and 5 afternoons of working autonomously.
General remarks	The number of participants is limited as every student needs his own workplace.

Course name	**Elektrische Schienenfahrzeuge**
Course code	**23346**
Lecturer/ Institute	Clos, Gerhard
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	Knowledge about electrical railway vehicles
Brief description course	The lecture explains different systems of the power electronic in railway applications.
Contents	History First trials locomotives with huge engines Development of locomotives until 1945 Standard locomotives Three phase locomotives comparison of traction systems efficiency infrastructure of tracks vehicle design fundamentals of railway traction vehicle dynamics Z-v diagram brakes railway power supply generation and distribution catenary and panthograph classic DC and AC locomotives current path transformers control power switches DC- and AC- machines chopper Three phase locomotives history basics induction motor converters DC link Thyristors, GTO and IGBT future developments mechanics undercarriage and bogie drives friction specialties Transrapid diesel-electric locomotives energy storage free wheel storage

	signaling SIFA INDUSI LZB ETCS
Lecture notes	The presentation is available on the web server of the Elektrotechnisches Institut
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Power Electronics for Regenerative Energy Sources**
Course code	**23347**
Lecturer/ Institute	Prof. Dr.-Ing. Burger / ETI
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Module Power Electronics
Objectives	The goal is to get a survey of the different possibilities of generating energy from regenerative sources. The students should attain special knowledge about photovltaics and power electronics for solar cells.
Brief description course	At first, a survey about regenerative energy generation is given in the lecture. After that, a special view is given on photovoltaic installations and solar cells.
Contents	Lecture The different possibilities of generating energy from regenerative sources are presented in this lecture. These are - wind energy - water power - solar heating - geothermal energy - photovoltaics The integration of these energy sources in existing power supply systems is explained in this lecture. Further themes are the isolated networks and energy storage systems. A focus of the lecture is on photovoltaics, the following themes are explained in detail. - PV-DC-systems - battery charge controllers - MPP trackers - PV - grid interconnections - inverter circuits - control of direct power / inductive power - characteristics of solar cells - system efficiencies The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Papers about the topics are distributed in the lesson.
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Knowledge in power electronics is recommended.

Course name	**Power Generation**
Course code	**23356**
Lecturer/ Institute	Dr. Hoferer / IEH
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	Power generation fundamental lecture. The lecture covers the entire topic of power generation from conversion of primary energy resources in coal fired power plants and nuclear power plants to utilisation of renewable energy. The lecture gives a review of the physical fundamentals, technical-economical aspects and potential for development of power generation both conventional generation and renewable generation.
Contents	Energy ressources Energy consumption Types and use of power plants Conversion of primary energy in power plants Thermodynamical fundamental terms Process in steam power plants Steam power plants components Flue gas cleaning Thermal power plants Nuclear power plants Hydroelectric power plants Wind energy converters Solar energy plants Use of power plants The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Material is available at the beginning of the lecture. Literature: Schwab; Elektroenergiesysteme.
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**High-Voltage Technology I**
Course code	**23360**
Associated Exercise	23362
Lecturer/ Institute	Dr.-Ing. Rainer Badent/IEH
Credit Points	3+1,5
Semester hours	2+1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic Network and Field Theory
Objectives	This course familiarizes students with a wide range of issues of High-Voltage Technology. It provides a deep insight in this special field of electrical engineering.
Brief description course	Electrical Fields, Dielectrics
Contents	Electric potential fields Maxwell's equations Calculation of static electric fields, charge simulation method Difference method, Finite-Element method, Monte-Carlo method, Boundary-element method Graphical field evaluation Measurement of electric fields, field energy and field forces Polarization, boundary layers, inclusions, DC and AC voltage distribution in dielectrics Frequency and temperature dependency of the dissipation factor Generation of high DC/AC and impulse voltages and high impulse currents for testing The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	Written

Course name	**High-Voltage Technology II**
Course code	**23361**
Associated Exercise	23363
Lecturer/ Institute	Dr.-Ing. Rainer Badent/IEH
Credit Points	3+1,5
Semester hours	2+1
Term	summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	High-Voltage Technology II
Objectives	This course familiarizes students with a wide range of issues of High-Voltage Technology. It provides a deep insight in this special field of electrical engineering.
Brief description course	Dielectrics Insulation Koordination
Contents	Gas discharges, gaseous electronics, atomic energy niveaus, self-sustained and non-self-sustained discharges Townsend mechanisms, channel mechanism, similarity laws, Paschen's law Glow discharges, sparks, arcs, partial discharges, breakdown of liquid and solid dielectrics Statistics of electrical breakdown Insulation coordination, roots of overvoltage's, trans-mission line equations, travelling wave theory The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Küchler, A. Hochspannungstechnik; Springer Verlag, 2005
Language	German
Examination	Written

Course name	**Power Network Analysis**
Course code	**23371**
Associated Exercise	23373
Lecturer/ Institute	Prof. Leibfried / IEH
Credit Points	3 + 3
Semester hours	2 + 2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Linear electrical networks, Electric Energy Systems
Objectives	The goal is to relay theoretical fundamentals in the field of electric power technology and power transmission.
Brief description course	In the first part the lecture deals with the basics of High-Voltage technology. Then the basics of transmission and distribution of electric energy is presented as well as the load flow calculation and the short-circuit calculation methods.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.

Contents

Lecture

In its first part, this lecture introduces the High-Voltage technology and its basics. Especially, the reasons for the necessity for the power transmission with high voltages are given. Basic electrical configurations and stresses occurring at multi dielectric systems are presented. Finally the first chapter deals with discharge phenomena.

The second chapter deals with the three phase system. Especially, the mathematical treatment of three phase systems and the introduction of component systems are contained in this chapter.

The third and very comprehensive chapter deals with the transmission and distribution of electric energy. Firstly, the laws of power transmission via transmission lines are presented. Then, the stability of electric power systems and possibilities to increase the power transmission capacity are discussed. Finally, the physics of energy distribution in the medium and low voltage grid is shown.

The fourth chapter deals with the Calculation of electric power networks and systems. Firstly, the preparatory steps for the calculation of the power network are shown. After discussing the basic network analysis methods, the load flow calculation are shown. Especially, the method of current iteration and the Newton Raphson method are presented and the algorithms of the individual methods are shown using an example.

The fifth chapter deals with methods for the calculation of the 3 phase short circuit. Thereby, it is distinguished between the short circuit nearby the generator and far from the generator.

In the sixth chapter the unsymmetrical faults in power networks and their calculation are discussed. Therefore, the symmetrical components are introduced as a first step. Then, the circuits in symmetrical components of all important power network equipment are presented. The chapter closes with the mathematical treatment of unsymmetrical short circuits using the symmetrical component method.

Exercises

To accompany the lecture, a collection of problems can be downloaded. During lecture hall exercises their solutions will be discussed.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.ieh.uni-karlsruhe.de and can be downloaded using a password.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IEH webpage (www.ieh.uni-karlsruhe.de).

Course name	**Power Transmission and Power Network Control**
Course code	**23372**
Associated Exercise	23374
Lecturer/ Institute	Prof. Leibfried / IEH
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Master
Elective course	Master
Prerequisites	Electric Energy Systems, Power Network Analysis
Objectives	The goal is to relay further and deeper theoretical fundamentals in the field of electric power technology and power transmission.
Brief description course	In the first part the lecture deals with the dynamic behaviour of synchronous generators. The second main chapter deals with HVDC, a technology for the transmission of a high amount of electric energy. Subsequently, FACTS are presented which help to increase the flexibility of power transmission systems. Finally, the dynamic behaviour of power stations and the entire power grid will be discussed.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.

Contents

Lecture

In its first part, this lecture introduces the dynamic behaviour of synchronous generators and the mathematical description. In a first step, the construction of synchronous generators is described. Then, the dq0 frame and its application for the mathematical description of the dynamic behaviour of synchronous generators is presented. Subsequently, the transition from the common mathematical description of synchronous generators towards the equations describing the steady state condition is shown. Then, transients are discussed at the example of a 60 Hz synchronous generator. Finally, the short circuit nearby the generator using the dq0 frame is discussed.

The second chapter deals with the HVDC technology. First of all, the characteristics of HVDC for power transmission are discussed. Then, line commutated current converters are introduced, especially the B6 circuit and 12 pulse current converters consisting of two B6 circuits switched in series are discussed. Then, the HVDC system configuration and components like filters, thyristors, smoothing reactors and converter transformers are presented. Finally, the basic control concept for HVDC transmission systems is shown.

The third and very comprehensive chapter deals with the technology and characteristics of FACTS, which can be used to increase the flexibility and the transmission capacity of power transmission systems. First of all the fields of application of FACTS are described. Then, the individual FACTS circuits and their mathematical description are presented, which can be divided into FACTS switched in series and parallel to the grid.

The fourth chapter deals with the dynamic behaviour of power stations and power grids. In the first part of the chapter, the system control modelling of power stations and power grids is presented. Then, the causes of frequency and voltage deviations in the grid are discussed. The main part of the chapter deals with the frequency control in the power grid. Finally, the voltage control of the power grid is presented.

	Exercises To accompany the lecture, a collection of problems can be downloaded. During lecture hall exercises their solutions will be discussed. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.ieh.uni-karlsruhe.de and can be downloaded using a password.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IEH webpage (www.ieh.uni-karlsruhe.de).

Course name	**Electronic Systems and EMC**
Course code	**23378**
Lecturer/ Institute	Dr. Sack / IHM
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	The goal is to relay practical knowledge in the design of electronic circuitry and systems with reduced sensitivity to electromagnetic interference
Brief description course	Based on the coupling mechanisms for electromagnetic interference the lecture gives an overview over different coupling paths for disturbance, the influence of the electromagnetic interference on the function of the system and measures for a system design less sensitive to electromagnetic interference.
Contents	Especially for electronic circuitry and systems in the industrial environment a high reliability and operational safety is required. For the design of such systems this means on one hand, that these systems need to be tolerant against electromagnetic interference and over-voltage, on the other hand, that electromagnetic noise emissions have to be limited to the allowed levels. Both is summarised under the generic term of electromagnetic compatibility (EMC). The lecture gives an introduction to different concepts for the design of electronic circuitry and systems according to the rules for an electromagnetic compatible design.

A basic element of analogue circuits is the operational amplifier. As an introduction the lecture deals with selected basic circuits and their calculation with reference to the individual characteristics of voltage feedback- and current feedback amplifiers.

For a subsequent digital processing an analogue signal has to be digitized. By the proper choice of the digitalisation technique in some cases a considerable noise cut-off can be achieved. Frequently sources for noise are placed next to noise-sensitive circuitry. One example are analogue-to-digital converters with the noise-sensitive analogue signals lying next to the fast rising digital signals. In the area of power electronics and high-voltage technique control- and measurement signals have to be led and processed next to high voltage and high current. The lecture describes different coupling mechanisms (galvanic, electric, magnetic, and radiation) for coupling noise between two circuits on different coupling paths. The typical coupling paths on printed circuit boards and measures for a reduction of noise emission and sensitivity to noise are explained.

When coupling single circuit boards or devices to complex systems the connection leads and cables for power supply and signals form coupling paths. The lecture deals with different concepts to reduce the noise coupled into such grids.

Especially when connecting devices to large grids or in the area of high-voltage technique and power electronics over-voltages caused by lightning or switching processes may occur. Based on the available devices for over-voltage protection the lecture presents different concepts for a protection against over-voltage.

Shielded housings reduce of noise emission and protect against disturbing noise from outside. The lecture describes the different shielding mechanisms for electric and magnetic fields and electromagnetic waves. Furthermore, it deals with the design of housings with shielded doors, cable connections, and more.

Filtering plays an important role in the reduction of noise emission over cables and in the noise cut-off. The lecture presents different passive and active filter designs and their application.

The measurement of noise emission enables testing devices with respect to their electromagnetic compatibility. The lecture describes common measurement methods and measurement environments.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Copies of the transparencies are distributed in the course of the lecture
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Photovoltaic system technology**
Course code	**23380**
Lecturer/ Institute	Dr. Heribert Schmidt / IEH
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	The fundamentals of photovoltaic systems technology will be presented.
Contents	Lecture Introduction Ways of solar energy utilisation The terrestrial solar radiation Solar radiation measuring principles Fundamentals of solar cells Overview of typical cell technologies Efficiency values Equivalent circuit diagram of solar cells Properties of solar cells and solar modules Series and parallel connection of solar cells Matching of solar generators and loads MPP-Tracking Construction of PV-modules Partial shading, bypass-technologies Overview of different System configurations Batteries for PV applications Charge controllers Battery peripherals Inverters for stand-alone systems Inverters for grid connected systems European efficiency Safety and EMC aspects Annual yield of PV systems Economic evaluation of PV systems Examples of realised PV systems The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Copies of the main transparenvies will be distributed each lecture. Literature: „Regenerative Energiesysteme“, Volker Quaschning, ISBN: 978-3-446-40973-6 „Photovoltaik“, Heinrich Häberlin, ISBN:978-3-8007-3003-2
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture
General remarks	The lecturer is member of the Fraunhofer Institute for Solar Energy Systems ISE, Freiburg.

Course name	**Windpower**
Course code	**23381**
Lecturer/ Institute	Dipl.-Phys. N. Lewald / IEH extern
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to relay basic fundamentals for the use of wind power.
Brief description course	Wind Power fundamental lecture. Focus of the lecture is basic knowledge for the use of wind power for electricity, complemented by historical development, basic knowledge on wind systems and alternative renewable energies.
Contents	Lecture The lecture contacts due to the broadly basic knowledge to all listeners of all terms. On the basis of an overview of alternative, renewable energy technologies as well as general energy data, the entrance is transacted into the wind energy by means of an overview of the historical development of the wind force. Since the wind supplies the driving power as indirect solar energy, the global and the local wind systems as well as their measurement and energy content are dedicated to its own chapter. Whereupon constructing the aerodynamic bases and connections of wind-power plants and/or their profiles are described. The electrical system of the wind-power plants forms a further emphasis. Begun of fundamental generator technology over control and controlling of the energy transfer. After the emphasis aerodynamics and electrical system the further components of wind-power plants and their characteristics in the connection are described. Finally the current economic, ecological and legislations boundary conditions for operating wind-power plants are examined. In addition to wind-power plants for electricity production, the lecture is also shortly aiming at alternative use possibilities such as pumping systems. Finally an overview of current developments like super-grids and visions of the future of the wind power utilization will be given. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	A scriptum that has to be overhault is available on http://www.ieh.uni-karlsruhe.de/windkraftanlagen.php Further book titles or relevant websites will be announced in the lecture. The lecture slides can be likewise downloaded from the lecture webpage.
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Technique of Electrical Installation**
Course code	**23382**
Lecturer/ Institute	Dr. Andreas Kühner / EnBW
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to relay practical fundamentals.
Brief description course	The lecture gives an overview about the classical and modern methods of electrical installations of and in buildings. Furthermore the students get an insight to regulations and engineer standards.
Contents	Lecture Capture 1 Electrical Power Distribution and Networking Capture 2 Electrical Power Supply of Buildings Capture 3 Electrical Power Supply in Buildings Capture 4 Protective Equipments Capture 5 Electrical Energy Applications Capture 6 Electrical Automation and System Engineering of Buildings Capture 7 Powermanagement of Buildings The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: http://www.ieh.uni-karlsruhe.de/elektrische_installationstechnik.php
Language	German
Examination	written
Formation of grade	Grades result from the written examination
Course form	Lecture

Course name	**Energy Economics**
Course code	**23383**
Associated Exercise	none
Lecturer/ Institute	Gerhard Weissmueller, Dr. Eng. / IEH
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to relay technical and economical interrelation in liberalised energy markets.
Brief description course	Advanced lecture combining the aspects of energy generation and transmission infrastructures and economics of energy supply: Based on the estimation of available primary energy resources technical and economical solutions for covering the long-term energy demand are discussed. The lecture deals with the structural change of markets from monopoly to competition and the mechanisms of the European electricity and natural gas market are explained. Market actors, products and pricing in a competitive environment as well as new strategic approaches for increase of energy efficiency and customer service are covered. Knowledge of interrelation and interactions within the global system of energy supply is imparted.
Brief description exercises	none
Contents	Lecture This lecture is scheduled for those students working on the diploma or masters degree in Electrical Engineering and focuses on interrelation and interdependency in the European energy market. Based on a statement of availability of fossil fuel resources the world energy consumption of the year 2030 is prognosticated as the result of a study by Exxon. Consequences in the manner and the extent of reasonable use of energy and energy production are deduced. Structure, legal framework and interrelation of the different market actors in the European energy market are described in detail. Basic understanding of complex procedures in these markets is achieved by the discussion of realistic examples. First of all the actual energy demand of Germany and the world is illustrated. Possibilities of specific energy savings and their impact on energy production and environment are shown. The prognosticated energy demand of the world in 2030 is measure for the necessary volume of energy production. Renewable energy generation plants are introduced as the reasonable and necessary complement of the previous fossil energy plants in respect of environment and energy efficiency. The European Union regulated the energy market by issuing a new legal framework. The lecture delves deeply with the change from monopoly to competition market structures. The changes for market actors especially for customers are presented and new structures and procedures as for example trading through energy stock exchanges are developed.

The market environment for energy trading and sales has changed fundamentally. Pricing for energy supply is more and more subjected to national and international influences. Costs of energy production, energy transport and mainly public dues and taxes are determining energy prices and reducing the sales benefits. New products shall gain additional business and turnover.

Essential basis for a competitive energy market is the deregulation of energy transport systems. In this lecture options for a further development of the infrastructure for energy transports are discussed with the objective of providing random network access to all market actors at the same price and service quality.

Competitive energy markets need a highly sophisticated provision of energy data. Energy data management as an essential basis for planning, forecast, production, transport as well as billing is illustrated and examples for technical realisations are shown.

Goals of the European legislation are increasing energy efficiency and quality of customer service. Meeting these requirements energy supply companies will have to create new solutions and possibly new systems. The previous energy supply system based on centralised structures may be expanded by decentralized supply structures for energy production and distribution. Delivery of electricity and natural gas may be more and more replaced by provision of energy services which are presented in this lecture as well.

Finally, company structures, business management and the statement of operations are shown under competitive energy market conditions.

Paper Presentations
Accompanying the lecture students are welcome to present a paper on a subject related to energy demand or supply which is in their interest. The subject of the presentation will be appointed in consultation with the lecturer. The power-point-presentation should preliminarily be sent to the lecturer. The speech presented in class should last about 20 minutes and questions should be answered in the following discussion. The results of such a voluntary presentation will be part of the final grades.

Field Trips
At least two field trips are offered to deepen the curriculum by experiencing subjects of energy economics in reality. Preferably field trips are organized to visit thermal and renewable power plants, network infrastructure for transport and distribution purposes as well as integrated power supply companies.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Lecture material will be provided directly by mail. At the beginning of the term accompanying literature will be recommended and a list of adjacent literature to deepen the knowledge and understanding of the curriculum will be delivered.
Language	German
Examination	Oral (Examination is taken on the curriculum of the entire lecture and all subjects documented in the provided lecture material).
Formation of grade	Grades result from oral examination. The additional voluntary presentation of a paper on an energy economical subject will be weighted by one third of the final grades.
Course form	Lecture, paper presentations, field trips
General remarks	The course comprises of eight interleaved lecture blocks amended with student presentations and at least two field trips visiting power supply facilities.

Course name	**Numerical field calculation in Computer Aided Design environments**
Course code	**23386**
Lecturer/ Institute	Dr. Schaub / ABB
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	Practical application of field simulation in state-of-the-art computer aided design environments
Brief description course	Computer aided simulation based design is nowadays common practice in engineering departments of the electrical power industry as well as in all other branches of industry. In order to reduce development cost and time and to avoid design errors already in early phases of the development process, future products are optimized using simulation models (so-called virtual prototypes) long before a physical prototype has to be build and tested. High performance hardware, together with efficient mathematical methods for modeling, simulation and visualization allow for a realistic representation of geometric and visual appearance of the future product as well as its physical properties and functionalities. The lecture aims to convey a basic understanding of the computer-aided product development process (commonly known as Computer Aided Engineering, CAE), and of the underlying methods and tools, whereas the main focus is on methods for numerical field calculation. The prospective engineer shall be enabled to work in a state-of-the-art environment for product development in an effective and efficient way.

Contents

Lecture

The lecture starts with an introduction to the process of computer aided product design. Methods, tools and data models which are available to the engineer in a state-of-the-art environment for simulation based product design are presented. Particular topics are goals and approach of simulation based design, product data management (PDM), product lifecycle management (PLM), product models as well as tools and methods for modelling, simulation, calculation and visualization.

The second part of the lecture is dedicated to the topic of simulation, which is the most important component of simulation based design. After an introduction of the different types and application areas of simulation, an emphasis is put on numerical field calculation, a type of simulation widely used in product development. The whole process of numerical field calculation, starting from modelling to solving and results visualization is explained.

After a review of some basics of field theory and discrete mathematics, an overview of field calculation methods is presented. Numerical, analytical and experimental methods are compared. The following part of the lecture is focused on numerical methods only, since these methods are of high significance for simulation based product design.

The following methods for numerical field calculation are discussed in detail:

- Finite difference method (FDM)
- Finite element method (FEM)

- Integral Methods

Mesh-free methods, e.g. Monte Carlo method

After a detailed discussion of these methods with emphasis on the Finite Element Method, some supporting methods the process of numerical field calculation are introduced. These are particularly methods for modelling and meshing (i.e. creation of a simulation model), as well as methods or the presentation of results and the calculation of secondary results. Since every numerical field calculation requires the solution of a large, linear or nonlinear system of equations, underlying mathematical methods are reviewed and compared with respect to their practical applicability.

The last part of the lecture deals with the hardware and software environment, which is needed for an efficient application of simulation based design in the context of product development. The main focus here is the deployment of parallel computing environments and the therefore required parallelization of the most critical algorithms.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	A script and all presentations used during the lecture are available as PDF files on CD. Further literature is mentioned at the end of each chapter in the script.
Language	German
Examination	oral
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	The lecture is offered biweekly as a block (4 units)

Course name	**Business Management for Engineers based on Case Studies**
Course code	**23387**
Lecturer/ Institute	Prof. Schröppel/IEH
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Key Qualification
Prerequisites	none
Objectives	The goal is to impart practical business management knowledge
Brief description course	The lecture introduces the engineering student with basic knowledge of business management needed in today's practical work. It gives him a foundation to act economically in his every day work as an engineer in his company.
Contents	Lecture 1. Introduction 2. Business plan 3. Budgeting and forward planning 4. Cost structures for personnel work 5.Prices for products and services 6. Management of projects 7.Calculation of return on investment 8. Evaluation of the value of a company 9. Balance sheet, profit and loss account, cash flow calculation The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The lecture notes are distributed during the courses. No further literature needed.
Language	German
Examination	Oral
Formation of grade	The grades result from the oral examination
Course form	Lecture
General remarks	none

Course name	**Design and Operation of Power Transformers**
Course code	**23390**
Associated Exercise	n.a.
Lecturer/ Institute	Dr.-Ing. M. Schäfer, IEH
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basics in electrical engineering
Objectives	The goal is to relay theoretical fundamentals about Power Transformers. Special scope is the design and its applications in energy grids.
Brief description course	Special lecture for power transformers. Main topics are the physical fundamentals and their application in transformer precalculation and design. Based on that the different variations in design and the various applications are discussed. Finally future trends and research and development activities in the field of power transformers are presented.
Brief description exercises	n.a.

Contents

Lecture

The lectue is divided into the following clauses
- Applications and design variations of power transformers
- Components and design of power transformers
- Working principle of power transformers and shunt reactors. Induction law and its application for the precalculation of transformers. The magnetic field in iron cores, core designs, variations and air gaps in magnetic circuits. Magnetic materials and their properties, application in transformers and shunt reactors. Main and stray flux in transformers and calculation of the equivalent circuit. Stresses inside transformers during inrush and short circuits.
- Winding connections and vector groups of transformers, three phase power system, connected voltages and line to earth voltage, description of three phase systems, parallel connection of transformers.
- Design and calculation of transformers.
- Losses in transformers and its origins in core and in the windings. Possible measures to influence loss generation. Cooling systems and its applications.
- High voltage DC transformers
- Factory testing of transformers. Performance of type tests, standard test and special tests.
- Overload capability of transformers. Controlled overloading and emergency overload.
- Service and monitoring.
- Future trends and research and development activities.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	The material is distributed during any lecture
Language	German

Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	The course consists of seven lecture blocks and one factory visit. Date and time is announced on the blackboards.

Course name	**Electric Energy Systems**
Course code	**23391**
Associated Exercise	23393
Lecturer/ Institute	Prof. Leibfried / IEH
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	Linear electrical networks
Objectives	The goal is to relay theoretical fundamentals in the field of electrical network analysis and in the field of electrical power networks.
Brief description course	In the first part the lecture deals with the calculation of transients in linear electrical networks using differential equations and the Laplace transform. In the second part of the lecture the electrical power network equipment is described.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.

Contents

Lecture

In its first part, this lecture is a consequent continuation of the calculation of electrical networks as it is presented in the lecture “Linear electrical networks”. In the second part of this lecture, the basics of electric power network equipment are presented. This is the basis for all further lectures of power system technology.

The first chapter gives an introduction in the single phase and three phase AC system.

The second chapter deals with or is a repetition of electro-magnetic basics. In a first step magnetic circuits and their calculation is treated. Then are subjects like main flux and stray flux are introduced, as well as self induction main inductance and stray inductance. The induction law leads directly to the transformer and the calculation of inductances and finally to the calculation of forces caused by a current flowing in a conduction which is located within a magnetic field.

The third and very comprehensive chapter deals with the mathematical description of electrical networks. Hereby, it is distinguished between networks with concentrated elements and networks with distributed elements. The calculation of networks with concentrated elements leads to differential equations with constant coefficients. Their solution as well as a special case, the sinusoidal excitation of such networks, is comprehensively demonstrated using examples. Finally, the description of electrical networks by a system of first order differential equations is shown and their solution is presented. Circuits with distributed elements are transmission lines. The transmission line theory for sinusoidal voltages and currents as well as for impulse voltages and currents is shown.

The fourth chapter deals with the Laplace Transform as a tool for electrical network analysis. First, the Duhamel integral (convolution integral) is presented. Then the Laplace Transform is derived out of the convolution integral and in a further sub-chapter the solution of differential equations using the Laplace Transform is demonstrated.

The fifth chapter deals with methods for network analysis. It demonstrates the mesh analysis, the nodal analysis, the superposition theorem, Norton's theorem, Thevenin's theorem and the Tellegen-Theorem. These formal methods are demonstrated using two examples circuits. These circuits are transistor amplifier with and without a transformer. This allows the calculation of networks with voltage or current dependent sources.

In the sixth chapter the structure of the electric power network is shown and explained.

The seventh chapter deals with power network equipment. Thereby, their steady state behaviour in the power network as well as their electrical and mechanical basic design is presented. The chapter contains synchronous generators, power transformers, reactors, capacitors, transmission lines and switch gear. For all of this power network equipment its steady state electrical circuit is derived. This gives the basis for all further lectures in the field of power network engineering.

Exercises

To accompany the lecture, a collection of problems can be downloaded. During lecture hall exercises their solutions will be discussed.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.ieh.uni-karlsruhe.de and can be downloaded using a password.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the IEH webpage (www.ieh.uni-karlsruhe.de).

Course name	**High-Voltage Test Technique**
Course code	**23392**
Associated Exercise	23394
Lecturer/ Institute	Dr.-Ing. Rainer Badent
Credit Points	3+1,5
Semester hours	2+1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	High-Voltage-Technology I and II
Objectives	This course familiarizes the students with issues of high voltage testing, calibration and the contents of the international test standards for high voltage testing.
Brief description course	This course familiarizes the students with issues of high voltage testing, calibration and the contents of the international test standards for high voltage testing.
Brief description exercises	Lightning Impulse Test PD-Measurement
Contents	- High voltage test technique - PD-measurement - Transformer testing - Cable and accessories - Switchyard - Insulators and transmission line fittings - Computer based test systems in the area of high voltage testing - Accreditation of test laboratories The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	oral

Course name	**Power System Analyses**
Course code	**23395**
Lecturer/ Institute	Dr.-Ing. Thomas Weber / Schneider Electric
Credit Points	3
Semester hours	2 + 0
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	Base knowledge on planning of electrical power systems
Brief description course	Overview on tasks and solution for the planning of electrical power systems
Contents	The following main topics are discussed: - Introduction - Electrical Power Systems - Symmetrical Components - Data of Equipment - Solution of linear equation systems - Short circuit calculation - Power flow calculation - Power system protection - Reliability analyses - Transient Stability Analyses - Application Examples The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Slides
Language	German
Examination	Oral examination
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Lecture Block (3 – 4 blocks)

Course name	**Automation of Power Grids**
Course code	**23396**
Lecturer/ Institute	Dr.-Ing. Roland Eichler / Siemens AG
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic knowledge of power transmission and distribution; basic knowledge of IT
Objectives	Understand methods, equipment, standards, current and future technology, state-of-the-art and trends of power systems control from a global (i.e. worldwide) perspective
Brief description course	The lecture conveys the bases of power systems control, whereby special value is attached to the application in the practice. Thus both current technologies are covered as well as technologies already applied in the field for some time. After a short introduction to the electrical energy supply as well as to the operation of electrical grids, i.e. to the environment of power systems control, the operational data dealt with in power systems control are analyzed. The lecture deals with the concepts and technologies of remote control and substation automation as well as technology applied in network control centers; the communication technology is non-specific for the power systems control and therefore gets only striped. A main emphasis of the lecture is on the software technical solutions for network control centers, i.e. on data models, data management as well as the architecture of software systems in control centers. The basic functionality of a network control center (SCADA = Supervisory Control And Data Acquisition) as well as its The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Slides of the lecture presentation
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Laboratory Electrical Power Engineering**
Course code	**23398**
Lecturer/ Institute	Dr.-Ing. K.-P. Becker / ETI
Credit Points	6
Semester hours	4
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Electrical Drives and Power Electronics, Electrical Energy Systems
Objectives	The goal is to acquire practical knowledge.
Brief description course	Based on the fundamental lectures on electrical machines, power electronics and electrical energy systems the student gain insight into the fundamental systems of Electrical Power Engineering.
Contents	Laboratory The Laboratory contains 8 fundamental experiments including the most important utilities of electrical power engineering: - stationary performance of the asynchronous machine - transformer - diode rectifier - speed variable drive system - high voltage diagnostic - high voltage generator - dielectric strength - partial discharge The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Material for this laboratory is available on the ETI homepage (www.eti.uni-karlsruhe.de).
Language	German
Examination	An oral examination will take place for every experiment (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	The final grades result from the arithmetic mean of the 8 grades from every experiment.
Course form	Laboratory
General remarks	Current information can be found on the ETI webpage (www.eti.uni-karlsruhe.de).

Course name	**Radar Systems Engineering**
Course code	**23405**
Lecturer/ Institute	Prof. Wiesbeck / IHE
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	None
Objectives	The goal is to understand the Radar principles and gain knowledge about modern Radar systems
Brief description course	Based on Electromagnetic field theory, the lecture provides fundamentals of radar principles, system parameters and advanced techniques related to the system hardware and processing. From this lecture students are expected to learn how system engineering practically contributes to a radar system implementation.
Brief description exercises	No exercise
Contents	Lecture

Subjects dealt in this lecture are closely related to the ongoing research works in the institute. The lecture starts with a short historical review of the development in radar systems. The further contents of this lecture are categorized into three major parts.

The first part of this lecture focuses on the fundamental disciplines required for understanding radar principles. The propagation phenomena of electromagnetic waves, such as reflection, diffraction, and scattering fundamentals, are important subject to understand the radar signal propagation and delivered target information. This subject is related to the derivation of the radar equation that is the most critical formula in radar system engineering. It is expected that the students develop the skill to derive the radar equation for various configurations and scenarios. The basic radar principles are introduced in this part as well as system parameters. A radar system performance is quantified by several system parameters like accuracy, false alarm rate, sensitivity, and noise parameter of the system. These system parameters are mathematically derived and the theoretical relation (trade-off) between parameters is addressed in this part.

The second part deals with radar system configurations and system features. The system configuration depends on the purposes and applications. This part introduces various radar system configurations from a pulse radar system to advanced radar concepts, such as Moving Target Indicator (MTI) and Synthetic Aperture Radar (SAR) and analyzes the system functionality. Furthermore, the details about system hardware and the subjects related to the system implementation are dealt, for example Radar Cross Section (RCS) measurement technique for system calibration. In addition, students are supposed to learn basic radar signal processing techniques that conduct the pulse compression. It is worth since the system performance can be evaluated by the quality of data efficiently recovered by the signal processing techniques.

The last part dedicates to introducing emerging techniques for future radar systems. A promising system concept with Digital Beam Forming (DBF) will be the main stream in this part. Compared to a conventional radar system based on the phased array antenna, the advantages and disadvantages are addressed at diverse angles. This advanced system concept is applicable to automotive radar systems and High Resolution Wide Swath (HRWS) SAR system. The lecture provides not only the technical description for the DBF radar system concept, but also challenges waiting for solutions, so that students could be encouraged to involve their master thesis on those topics.

The lecturer reserves the right to alter the contents of the course without prior notification.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: http://www.ihe.uni-karlsruhe.de/805.php Literature: Werner Wiesbeck, Lecture script „Radar Systems Engineering.“
Language	English
Examination	Written (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture
General remarks	Current information can be found on the IHE (http://www.ihe.kit.edu) webpage.

Course name	**Fundamentals of Microwave Engineering**
Course code	**23406**
Associated Exercise	23408
Lecturer/ Institute	Prof. Zwick / IHE
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	Basic knowledge of higher mathematics, of linear electrical networks, of fields and waves and of electric circuits.
Objectives	The lecture covers theoretical basics together with a first overview of microwave components and systems.
Brief description course	Basic lecture of microwave engineering: the main topics of the lecture are to give a basic knowledge of microwave engineering as well as the methods and mathematical basics for the design of microwave systems. Essential areas are passive devices and linear circuits at higher frequencies, transmission line theory, microwave network analysis and an overview of microwave systems.
Brief description exercises	Accompanying exercises to the lecture are given concerning the lecture content. The exercises are discussed in a lecture hall tutorial and the corresponding solutions are explained in detail. Additionally, the most important contents of the lecture are repeated in the tutorial.
Contents	Lecture

This lecture is an introduction to the fundamentals of microwave engineering scheduled for Bachelor students of electrical engineering in the 5th semester. Having already prerequisites in the area of fields and waves, circuit theory as well as higher mathematics, the students are taught methods and mathematical basics for the design of microwave systems. Furthermore, the lecture will communicate the fundamentals, which are necessary for all other lectures in the area of microwave engineering.

At the beginning of the lecture the behaviour of passive devices (e.g. resistors, capacitors, inductors) at higher frequencies is analysed and the limits of reasonable usage are determined using equivalent circuits. In this context also optimum configurations for devices at higher frequencies are discussed. The various circuits for compensation of parasitic blind elements are the task of a further chapter.

One of the main fundamentals of microwave engineering is the circuit theory. After introducing the equivalent circuit and the derivation of the telegraph equation the propagation of waves on transmission lines is discussed in detail. This includes also approximations for lossy transmission lines. Starting from the transmission line theory the diverse applications of transmission lines at higher frequencies for transformation and matching as well as a blind element are given in the following. In this context the Smith diagram is introduced and discussed in detail. The description of the most important transmission line types of microwave engineering (coax line, waveguide, microstrip line) together with their characteristic parameters closes these considerations.

In the following chapter the fundamentals of microwave network analysis are treated. First, the different matrices (impedance, admittance, ABCD, scattering matrix etc.) are introduced and their application is demonstrated. The special properties of microwave networks as well as the connection of multi ports are further topics of this chapter.

After the fundamentals for a common comprehension of microwave engineering are available the next comprehensive chapter gives a first insight into the world of microwave systems. First, the most important components (antennas, propagation channel, amplifiers, mixers etc.) of microwave systems and their essential system parameters are introduced. Based on this an overview of modern microwave systems (e.g. radio wave propagation, radar) is given to grant a good first insight into microwave engineering.

Exercises

Accompanying exercises to the lecture content and the corresponding solutions are given and discussed in a lecture hall tutorial. Moreover, computer tutorials are offered where various microwave engineering problems discussed in the lecture are implemented in Matlab and the functionality is visualised.

The lecturer reserves the right to alter the contents of the course without prior notification.

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Language	German
Examination	Written (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture, Exercises
General remarks	The lecture consists of the two closely intermeshed parts lecture and tutorial as well as an additional offer of Matlab based exercises. Current information is available on the webpage of the IHE (www.ihe.kit.edu).

Course name	**Microwave Engineering**
Course code	**23407**
Associated Exercise	23409
Lecturer/ Institute	Prof. Zwick / IHE
Credit Points	4,5 + 1.5
Semester hours	3 + 1
Term	Winter term
Bachelor/ Master	Master
Elective course	Master
Prerequisites	Basic knowledge of higher mathematics, of linear electrical networks, of fields and waves, of electric circuits, semiconductors and fundamentals of microwave engineering.
Objectives	The lecture aims at giving a deep insight into microwave engineering with the emphasis on passive and active devices of microwave circuits.
Brief description course	Specialisation lecture about microwave engineering: the main tasks of the lecture are the functionality of the most important passive and active microwave components starting from waveguides to filters, couplers, directional lines and circulators as well as amplifiers, mixers and oscillators.
Brief description exercises	Accompanying exercises to the lecture are given concerning the lecture content. The exercises are discussed in a lecture hall tutorial and the corresponding solutions are explained in detail. Additionally, the most important contents of the lecture are repeated in the tutorial.
Contents	Lecture This lecture gives a deep insight into passive devices of microwave technology intended for students in the first semester in the master program of electrical engineering. Based on fundamental knowledge of microwave engineering (fields and waves, transmission line theory, microwave network analysis) the passive and active components of microwave circuit theory are emphasised. Furthermore, the lecture imparts insight into microwave system technology. An essential characteristic of microwave engineering is that the physical effects are hard to comprehend and complex to measure. On the other hand the geometrical form often reveals the function. Thus, many demonstration objects are shown in this lecture to produce an optimal comprehension of the complex matter. At the beginning of the lecture there is a short recapitulation of essential electromagnetic wave fundamentals and their propagation. Afterwards, different transmission lines (waveguide, coax line, microstrip line) are discussed in detail. Moreover, microwave resonators with practical examples are presented. A good comprehension of the functionality of passive microwave components is absolutely necessary in the microwave circuit theory. Thus, this topic is emphasised in the lecture. Based on the fundamentals treated before the main passive components like filters, junctions, couplers as well as ferrite-based components (e.g. circulators) are discussed. Besides the theoretical analysis also the practical understanding is fostered by the presentation of various applications.

As there exist several separate lectures concerning active microwave circuits this topic is treated only shortly here. The introduction of the most important active microwave components like detectors and mixers, amplifiers and oscillators with their functionality complete the lecture and the overview of the microwave technology.

In the last part of the lecture different microwave systems are introduced exemplarily. Especially the requirements for the single components are considered to give the students an understanding of the relation between the performance of the whole system and the specifications of the single microwave components.

Exercises

Accompanying exercises to the lecture content and the corresponding solutions are given and discussed in a lecture hall tutorial.

Tutorial
Moreover, an optional tutorial is offered for this lecture where the participants learn to handle commercial microwave software and thus gain skills of practical relevance. The tutorial “simulation of passive microwave components with CST Microwave Studio” was first offered in the winter term 2007/2008 in cooperation with industry. Since then it takes place every winter term because of the positive resonance. During six afternoon sessions with four hours each – besides an introduction by CST course personnel – the following contents are deepened and implemented: the design of a band pass filter (in microstrip technology), the simulation of diverse transmission line junctions (e.g. Wilkinson divider), the development and the simulation of a rat race coupler as well as the design of a circulator. All participants receive an attendance certificate.

The lecturer reserves the right to alter the contents of the course without prior notification.

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Lecture notes	Material to the lecture can be found online at www.ihe.kit.edu.
Language	German
Examination	Written (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture, Exercises
General remarks	The lecture consists of the two closely intermeshed parts lecture and tutorial as well as an additional optional tutorial. Current information is available on the webpage of the IHE (www.ihe.kit.edu).

Course name	**Antennas and Antenna Systems**
Course code	**23410**
Associated Exercise	23412
Lecturer/ Institute	Prof. Zwick / IHE
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic knowledge of higher mathematics, of fields and waves and fundamentals of microwave engineering.
Objectives	The lecture aims at giving a deep insight into antennas and antenna systems.
Brief description course	Specialisation lecture about microwave engineering: the main tasks of the lecture are the functionality of all essential antenna structures as well as an insight into modern antenna systems.
Brief description exercises	Accompanying exercises to the lecture are given concerning the lecture content. The exercises are discussed in a lecture hall tutorial and the corresponding solutions are explained in detail. Additionally, the most important contents of the lecture are repeated in the tutorial.

Contents

Lecture

This lecture concerning antennas and antenna systems is a specailisation in the area of microwace engineering and is intended for students in the 2nd semester of Master in electrical engineering. Besides the theoretical basics this lecture emphasises the practical implementation of the various antenna types. Comprehensive examples of all variations from single element antennas to complete base station antennas for mobile telephony make an optimum combination of theory and praxis possible.

At the beginning of the lecture there is a short recapitulation of essential electromagnetic wave fundamentals (Maxwells equations, plane wave). Afterwards, characteristic parameters of antennas (gain, antenna pattern etc.) and the electrodynamic potentials are defined. Using the latter the Hertzian dipole is derived. Based on this linear antennas are treated in detail. Considerations to antenna groups complete this part of the lecture.

Aperture antennas are widely spread (e.g. for satellite communications). Therefore, a separate chapter is dedicated to this group of antennas. After an introduction to the general theory of area radiators the main representatives of this category, the horn antenna and the lens antenna, are discussed in detail.

The duality principle is introduced for the theoretical treatment of the slot antenna. Furthermore, special dipoles (e.g. Yagi antenna) are presented.

Broadband antennas run through a fast development caused by increased demand. Thus, this lecture treats the different concepts for frequency independent or ultra wideband antennas in detail.

The measurement of antennas is a very special area of the microwave measurement technique. In a separate chapter the state-of-the art measurement techniques for the gain and the antenna pattern of an antenna are described.

In the last part of the lecture different antenna systems are introduced and their configuration as well as the functionality are discussed in detail. Especially the determination of the total performance and the requirements for the single elements are emphasised. Moreover, the consequences of non-ideal behaviour are considered. To visualise the contents examples of current antenna systems are given.

Exercises

Accompanying exercises to the lecture content and the corresponding solutions are given and discussed in a lecture hall tutorial.

Tutorial
The tutorial offers the possibility to put the theoretical content of the lecture into practice. The participation is optional and thus not relevant for the examination.

The tutorial aims at the design, the assembly and measurement of an antenna, usually in planar technology. CST microwave studio is used as design and simulation tool. The tutorial features six afternoon sessions (each 3.5 hours). Three of those afternoons are held in a pool room of the Steinbuch centre for computing and the remaining three afternoons comprise the assembly and measurement of the antenna in the IHE laboratory.

The first two afternoons comprise a general introduction to CST microwave studio and the finite integration method used by the program. This includes modelling of structures, the definition of waveguide ports as well as boundary and symmetry conditions, the consequences and influences of the discretisation (meshing), the application of the available solvers and the visualisation of the simulation results. On the third afternoon the students design their own antenna independently.

On the fourth afternoon the designed antenna is assembled in the IHE microwave laboratory. On the fifth afternoon there is a practical demonstration of the antenna measurement facility, which can be applied on the last afternoon, when the antenna patterns are measured in the IHE anechoic chamber.

The lecturer reserves the right to alter the contents of the course without prior notification.

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Lecture notes	Material to the lecture can be found online at www.ihe.kit.edu.
Language	German
Examination	Oral (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture, Exercises
General remarks	The lecture consists of the two closely intermeshed parts lecture and tutorial as well as an additional optional tutorial. Current information is available on the webpage of the IHE (www.ihe.kit.edu).

Course name	**Wave Propagation and Radio Channels for Mobile Communications**
Course code	**23411**
Associated Exercise	23413
Lecturer/ Institute	Dr.-Ing. T. Fügen/ IHE, Dipl.-Ing. M. Janson/ IHE, Dipl.-Ing. L. Reichard / IHE
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Bachelor/Master
Compulsory course	Bachelor/Master
Elective course	For IK
Prerequisites	Fundamentals on Mathematics, Electrodynamics, High Frequency Techniques, and Communications Engineering
Objectives	To convey the theoretical background of wave propagation and radio channels for analogue and digital mobile radio communication systems and networks.
Brief description course	Focus of the lecture is the procurement of fundamental knowledge for the description and calculation of the propagation of electromagnetic waves in mobile radio communications systems. Essential subject areas are the description of the propagation effects free space propagation, reflexion, scattering and diffraction, the characterisation of the system-theoretical properties of the radio propagation channel, wave propagation models, procedures for network planning, and fundamentals of multiple antenna systems (MIMO).
Brief description exercises	Accompanying to the lecture exercises are given concerning the lecture content. The exercises are discussed in a lecture hall tutorial and the corresponding solutions are explained in detail. Additionally, the most important contexts of the lecture are repeated in the tutorial.
Contents	The design and the planning of modern analog and digital mobile radio communications systems requires sophisticated tools for a prediction of the system performance before ever building the system. Course and tutorial teach the fundamentals needed for the development and/or usage of these design tools. They provide a detailed understanding of the physical wave propagation channel between the transmitting and the receiving antenna ports, including the description of all relevant wave propagation effects (e.g., free space propagation, influence of the antennas, reflection, transmission, scattering, diffraction, multipath propagation, spatial interference pattern etc.). Following an overview over common empirical and deterministic wave propagation models (e.g., Okumura- and COST-Hata model, ray-optical models) as well as physical and analytical channel models are given. The most important functions and parameters for a characterization of the time variant and frequency selective propagation channel are introduced (e.g., Rice and Rayleigh fading, log-normal fading, power delay profile and delay spread, Doppler spectrum and Doppler spread etc.). In addition course and tutorial also give a brief introduction into frequency planning and interference reduction techniques and trunking. In addition the fundamentals of smart antenna systems (MIMO: multiple input multiple output) are taught. The lecturer reserves the right to alter the contents of the course without prior notification.

	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Material to the lecture can be found online at www.ihe.kit.edu.
Language	English
Examination	Written (see current document "Studienplan" and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture, Exercises
General remarks	Current information is available on the webpage of the IHE (www.ihe.kit.edu).

Course name	**Microwave Laboratory II**
Course code	**23415**
Lecturer/ Institute	Prof. Zwick and academic staff / IHE
Credit Points	6
Semester hours	4
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The laboratory will give practical experience in the areas covered theoretically in the lectures. Moreover, the handling of microwave measurement apparatus and microwave components are trained.
Brief description course	“Practice-orientation by modern equipment and current problems”. This is the motto of this contemporary and technically challenging microwave laboratory. The experiments shall give practical experience in the areas covered theoretically in the lectures and train the handling of microwave measurement apparatus and microwave components. In groups of 2-4 students eight different experiments are accomplished and journalised. The order and topics of the experiments may vary.

Contents

Laboratory:

1. Analysis of passive devices using time domain reflectometry
Abstract: The reflexion behaviour of a voltage step at various passive measurement objects (R, L, C, discontinuities of the transmission line, resonant circuit) is investigated using time domain reflectometry.

2. Analysis and characterisation of microwave mixers
Abstract: Analysis of the characteristic mixer parameters (conversion loss, 1 dB compression point, dynamic range) for different mixer types at microwave frequencies.

3. The software tool ADS used for the simulation of active and passive circuits

Abstract: In this experiment the handling with a simulation tool (Agilent ADS) is taught. On the basis of active and passive filter circuits (RLC, stepped impedance filter…) the handling with the software is trained and some filter circuits are investigated in microstrip technology.

4. Noise figure measurement of active microwave components
Abstract: At a state-of-the-art noise measurement apparatus as used in industry the noise characteristic of amplifiers, attenuators and transmission lines are determined. Based on the single components the behaviour of ladder networks is investigated.

5. Antennas and antenna measurement: horn antennas, patch antennas and arrays

Abstract: For horn antennas and patch antennas the basic properties (matching, gain, antenna pattern) are investigated for single antenna elements as well as for phased antenna arrays (beam forming, side lobes).

6. Analysis of linear antennas with a network analyser
Abstract: Simple antenna structures are measured using a network analyser. Basic relations of linear antennas are acquired.

7. PLL stabilised microwave oscillator (VCO)

Abstract: The basic functionality of resonator oscillators are presented in theory and practical example. The practical relevance of important parameters like e.g. quality, phase noise and frequency stability is explained. Using two state-of-the-art oscillators the time and frequency behaviour is measured for actual electronic devices.

8. Analysis of analogue and digital demodulation methods
Abstract: Measurement and analysis of the most important analogue and digital demodulation methods (AM, FM, impulse, I/Q and other) for modern communications and sensor systems.

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Lecture notes	Material to the lecture can be found online at www.ihe.kit.edu.
Language	German
Examination	Each laboratory group has to prepare some exercises before the experiment as homework and to hand one copy to the corresponding supervisor. The exercises of the experiment are performed and journalised during the experiment. The journal has to be handed to the supervisor directly after the experiment. Before the start of each experiment there is a written or oral exam (30 min, no aids allowed) about the experiment content (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	The grade for each experiment consists of the homework (25%), the journal (25%) and the written or oral exam (50%). The final grade is the arithmetic mean of all eight experiments.
Course form	Laboratory in groups of 2-4 students
General remarks	General advise can be found at www.ihe.kit.edu

Course name	**Semiconductor Circuits for microwave and millimeter-wave application**
Course code	**23419**
Associated Exercise	23421
Lecturer/ Institute	Prof. Kallfass / IHE
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fundamentals of Microwave Engineering (recommended)
Objectives	To convey the theory and implementation of linear millimeter-wave monolithic integrated circuits.
Brief description course	This lecture conveys the theory and implementation of millimeter-wave monolithic integrated circuits (MMICs). The focus is on active linear circuits for applications up to and beyond 300 GHz as well as oscillators. The components and building blocks MMICs and their operating principle are covered.
Brief description exercises	Using a modern CAD design environment, actual circuit examples from the lecture will be implemented. Besides the circuit design and analysis, the physical layout of the MMIC will be carried out.

Contents

Lecture

The advances in speed and efficiency of modern transistor technologies enable the availability of the entire millimeter wave frequency range for compact, cost-effective, active electronics.

Based on the lecture “Fundamentals of Microwave Engineering”, the building blocks of active, linear circuits for the microwave and millimeter-wave frequency range are treated. The key components are passive linear elements, such as transmission lines, capacitors and inductors, and active elements such as transistors.

The working principle of the passive elements and their application in MMICs is covered. The transistor technologies that are suitable for the frequency ranges are introduced and their advantages and disadvantages are discussed.

The second part of the course introduces design concepts and implementation of an analogue front end in the millimeter wave range. The focus lies on linear components including low noise amplifiers, broadband traveling wave amplifiers. In the design of nonlinear circuits concepts for power amplifiers and oscillator are discussed.

Beyond the principles of circuit design and layout each chapter also covers aspects of circuit-oriented modeling and analysis of relevant characteristics.

In addition to the latest III-V compound semiconductor-based technologies, the lecture also deals with recent developments in the field of silicon transistor technology and develops an understanding of the respective advantages and limitations.

The lecturer reserves the right to alter the contents of the course without prior notification.

Exercises

	Accompanying the lecture the treated circuit are evaluated in a Simulation with recent CAD tools during the tutorials. Additionally necessary techniques and procedures during the development of processable MMICs are covered. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Material to the lecture can be found online at www.ihe.kit.edu.
Language	German
Examination	Oral (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture, CAD design hands-on
General remarks	Current information can be found at the internet page of the IHE (www.ihe.kit.edu).

Course name	**Microwave Measurement Techniques**
Course code	**23420**
Associated Exercise	23422
Lecturer/ Institute	Prof. Thumm / IHE
Credit Points	04. Mai
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fundamentals on High Frequency Techniques
Objectives	The goal is to relay theoretical fundamentals and an understanding of basic measurement setups.
Brief description course	This course contains all the essential components of today's high frequency measurement techniques. Particular attention is given to the description of measurement systems and methodologies used in modern applications. A one-day excursion to companies that produce high-frequency measurement equipment and components is offered.
Brief description exercises	Accompanying the lecture, exercises are discussed and the lecture content is deepened in lecture hall exercises. In addition, a half-day experimental course is offered in the laboratory, as well as an excursion to an RF and microwave company.
Contents	Lecture

The lecture deals with the fundamental principles and gauges from today's high-frequency measurement systems. The course requires a basic understanding of RF technology and is conceived for 8th semester students.

The introduction of the lecture sets the necessary basics and provides the measurable parameters such as frequency and power up front. Additionally features specific to the measurement in the microwave frequency region are pointed out.

The first components are the measurement generators. First up follows a classification of generators, which are then discussed in detail. These generators include signal-, sweepgenerators and synthesizers. Assemblies, circuits, and typical block diagram of the oscillators used as the heart of measurement generators are presented. The conclusion of this part is the investigation of the output spectra of these generators.

In the following power and frequency measurements are discussed. For power measurements principal sources of error as well as the actual detectors are presented. As an example, the calorimeters, bolometers or Schottky diode are mentioned. Power measurements of pulsed and modulated signals conclude the power measurement topic. Concerning frequency measurements mechanical and electronic measurement gauges are explained. Block diagrams and procedures, both for the direct measurement as well as the heterodyne measurement principle are discussed.

Now to measure an entire spectrum and not just a single frequency the spectrum analyzer is introduced. After the fundamentals of spectral analysis follows the block diagram with the components of an analyzer. This part concludes with the physical limitations of such analyzers and application such as the measurement of spectra of modulated signals.

As a gauge of the modulation range, the frequency-time analyzer is discussed. Topics here are the zero dead time counters as the heart of the analyzer as well as measurements of frequency and phase dynamic, jitter and specific pulse compression modulations for Radar signals.

In the penultimate part of the lecture the measurement of phase noise is presented. After the an introduction the causes of phase noise and the definition of the various observables are discussed. Subsequently the different methods of measurement such as the direct measurement method, the phase discriminator method, the frequency discriminator method and Allan variance measurements in time domain are explained. At the end of this section, a comparison of the different presented methods is displayed.

The conclusion of the lecture is the linear network analysis. This begins with the presentation of the structure of a network analyzer. In addition, the difference between scalar and vector network analysis is shown. Besides the calibration of such network analyzers and the introduction of error models necessary to describe the calibration, Frequency Domain Reflectometry (FDR) is presented.

Exercises

Accompanying the lecture exercises as well as the lecture topics are deepened in a lecture hall exercise. In addition, an experimental half-day lecture in the laboratory is offered, which shows the measuring instruments in practice. Some standard measurements are presented. A one day excursion to a high-frequency technology company gives students an insight into the work of a radio frequency engineer.

The lecturer reserves the right to alter the contents of the course without prior notification.

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Lecture notes	Literature: Thumm, M., Wiesbeck, W., Kern, S., Hochfrequenzmesstechnik-Verfahren und Messsysteme, BG. Teubner Verlag, Stuttgart, 2nd edition, 1998.
Language	German
Examination	Oral (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture, exercises, experimental lecture and excursion
General remarks	The course comprises of the interleaved lecture blocks and exercises. Additionally students get practical experience through the experimental lecture and the visit to a high-frequency technology company. Current information can be found on the IHE (www.ihe.kit.edu) webpage.

Course name	**Spaceborne SAR Remote Sensing**
Course code	**23424**
Lecturer/ Institute	Prof. Moreira / IHE
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	keine
Objectives	Fundamentals, Theory and Applications of spaceborne Radar systems
Brief description course	The lecture is very interdisciplinary and well suited to students interested in learning different aspects of the entire end-to-end system chain of spaceborne radar systems. Today, synthetic aperture radar (SAR) systems are generating images of the Earth surface with a resolution better than 1 meter. Due to the their ability to produce high-resolution radar images independent of sunlight illumination and weather conditions, SAR systems have demonstrated their outstanding capabilities for numerous applications, ranging from environmental and climate monitoring, generation of three-dimensional maps, hazard and disaster monitoring as well as reconnaissance and security related applications. Only recently we entered a new era of spaceborne and airborne SAR systems. New satellite systems like TerraSAR-X and TanDEM-X provide radar images with a resolution cell of more than a hundred times better than the one of conventional SAR systems. The lecture will cover all aspects of spaceborne radar systems as well as an overview of new technologies and future developments.
Brief description exercises	Supporting the main lecture, exercise assignments are distributed to the students. The exercise solutions are presented and discussed in details during lecture hall exercises. Subsequently more dedicated exercise assignments and selected topics are offered are explained to deepen the understanding of the main lecture contents.
Contents	Contents of the lecture are: Introduction to Synthetic Aperture Radar (SAR), theory and basic signal processing, system design and performance estimation, advanced SAR imaging modes, spaceborne SAR missions, technology development, applications (land, vegetation, sea, ice/snow, disaster monitoring, etc.), innovative SAR concepts and future developments. The contents of this lecture are closed related to the projects and research activities being performed at the Microwaves and Radar Institute of the German Aerospace Center (DLR, for more information please refer to www.dlr.de/HR). The lecturer reserves the right to alter the contents of the course without prior notification. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Material to the lecture can be found online at www.ihe.kit.edu or ftp://sar-lectures@www.microwaves-and-radar.dlr.de
Language	English
Examination	Written (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and exercises
General remarks	Actual information can be found at the internet page of the IHE (www.ihe.kit.edu).

Course name	**Modern Radio Systems Engineering**
Course code	**23430**
Associated Exercise	23431
Lecturer/ Institute	Prof. Zwick / IHE
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic knowledge of microwave and communications engineering
Objectives	At the end of this lecture the students will understand how to design an analogue frontend for a radio system on a block diagram level. Especially the non-idealities of typical radio frequency (RF) building blocks and their effects on the overall system performance will be part of the acquired knowledge.
Brief description course	The course gives a general overview of radio systems with their components. Thereby the focus is on the analogue parts of the system with their non-idealities. Based on the physical functionality of the various building blocks parameters are derived, which allow the consideration of their influence on the overall radio system performance.
Brief description exercises	The tutorial is closely related to the lecture with mainly computer based exercises to visualize the influence of any non-idealities on the overall system and demonstrate modern radio systems engineering.
Contents	1. Introduction to radio systems - Overview over wireless communication systems - Modulation and detection - Typical system performance parameters - System components 2. Radio channel fundamentals and antennas - Wireless radio channel - Antenna parameters 3. Noise - Noise sources - Noise temperature, noise figure, signal-to-noise ratio - Noise figure of cascaded stages - Mixer noise calculation - Noise calculation in base band 4. Non-linearity and time variance - Effects of non-linearity: gain compression, inter-modulation - Cascaded nonlinear stages 5. Sensitivity and dynamic range 6. Transceiver Architectures - Transmitter architectures: heterodyne/homodyne - Receiver architectures: heterodyne/homodyne, image-reject, digital-IF, sub-sampling - Oscillators: phase noise, oscillator pulling and pushing 7. Case studies - Generic PSK system - UMTS receiver - FMCW Radar

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Lecture notes	Material to the lecture can be found online at www.ihe.kit.edu.
Language	English
Examination	Oral (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found at the webpage of the IHE (www.ihe.kit.edu).

Course name	**Seminar Radar and Communications Systems**
Course code	**23432**
Lecturer/ Institute	Prof. Zwick / IHE
Credit Points	04. Mai
Semester hours	3
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fundamentals of Microwave Engineering
Objectives	The seminar wants to give an overview about the different tasks in microwave engineering. Special emphasis is given to practice the literature research, presentation techniques and the preparation of documentation.
Brief description course	The seminar enables the students to learn and consolidate presentation techniques as well as literature research and the preparation of documentation. Even though these skills are crucial qualifications in the professional life they are sparsely fostered during the course of studies. On the contrary, during the seminar each participant works independently on his own task (mainly English literature) and presents the task in front of the group. In the following there is a discussion not only about the technical aspects but also about the presentation and documentation style. Besides the presentation the obligatory written documentation in LaTeX prepares the students for the requirements of research projects and technical theses.
Contents	Different tasks associated to “Radar and Communications Systems” are handed to the participants. Working on the tasks has to be done independently by the students. Each participant prepares a written documentation about his topic and presents the topic in a presentation. The idea is not to gain new scientific results but to prepare partly known and solved problems in an understandable and new way. The lecturer reserves the right to alter the contents of the course without prior notification. The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German and English
Examination	Written documentation (paper) and presentation of the own work (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result mainly from the presentation and the written documentation
Course form	Looked after, independent working
General remarks	Current information is available on the webpage of the IHE (www.ihe.kit.edu).

Course name	**Active Integrated Circuits for Millimeter-Wave Applications**
Course code	**23441**
Associated Exercise	23431
Lecturer/ Institute	Prof. Kallfass / IHE
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Hoch- und Höchstfrequenzhalbleiterschaltungen (recommended)
Objectives	To convey the theory and implementation of millimeter-wave monolithic integrated circuits.
Brief description course	This lecture conveys the theory and implementation of millimeter-wave monolithic integrated circuits (MMICs). The focus is on active non-linear, frequency-translating circuits for applications up to and beyond 300 GHz as well as high-speed mixed-signal circuits. The components of modern analog frontends in communication and remote sensing systems are covered, including millimeter-wave transmitter and receiver architectures.
Brief description exercises	Using a modern CAD design environment, actual circuit examples from the lecture will be implemented. Besides the circuit design and analysis, the physical layout of the MMIC will be carried out.

Contents

Lecture

The advances in speed and efficiency of modern transistor technologies enable the availability of the entire millimetre-wave frequency range for compact, cost-effective, active electronics.

Based on the lecture “Hoch- und Höchstfrequenz-Halbleiterschaltungen” in the winter term, the major millimetre-wave applications and the usable semiconductor technologies are reviewed and put in context.

The second part of the course introduces design concepts and implementation of analog frontends in the millimetre-wave range. The focus is on frequency-translating components, including mixers and frequency multipliers, as well as ultra-fast switches.

On this basis, the treated sub-components are integrated into multi-functional MMICs, and their implementation in broadband transmit and receive systems is shown.

Mixed signal circuits for high data rates, with special consideration of parasitic effects when designing for maximum attainable speed, conclude the lecture.

Beyond the principles of circuit design and layout each chapter also covers aspects of circuit-oriented modelling and the analysis of relevant circuit characteristics.

In addition to the latest III-V compound semiconductor-based technologies, the lecture also deals with recent developments in the field of silicon transistor technology and develops an understanding of their respective advantages and limitations.

The lecturer reserves the right to alter the contents of the course without prior notification.

Exercises

Accompanying the lecture, the covered circuit types are evaluated using modern CAD simulation tools during the tutorials. Additionally, necessary techniques and procedures for the development of realizable MMICs are conveyed.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Material to the lecture can be found online at www.ihe.kit.edu.
Language	English
Examination	Oral (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture, CAD design hands-on
General remarks	Current information can be found at the internet page of the IHE (www.ihe.kit.edu).

Course name	**Digital Broadcast Systems**
Course code	**23444**
Lecturer/ Institute	Dr. Quellmalz / IHE
Credit Points	4,5
Semester hours	3
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basics of electrical engineering
Objectives	Linking of theoretical basics with their application in practice
Brief description course	This lecture shows the theoretical basics for the understanding of modern digital broadcasting systems and their application in practice. The centre of attention are the functionality and the optimization of the end-to-end system considering technical, economical, political and legal constraints.
Contents	The distribution of radio and television programs is in a radical change from analogue to digital transmission systems. DAB, DAB+, DMB, DVB-T, DVB-H, DRM, DRM+, HD-Radio – even this uncomplete enumeration shows that a variety of possibilities for digital broadcasting has been coming along the last years. How to these systems work? What do they have in common, what distinguishes them? What are the advantages and disadvantages? Which compromises had to be made in system development? These questions are discussed in close connection of theory and pratice. Initially the lecture goes into methods of digitizing analogue audio and video signals, in particular into the relationship of bitrate and quality which is a very important point of view in broadcasting. An efficient source coding is a main prerequisite for digital broadcasting because the high frequency spectrum is a valuable resource for wireless transmission. The fundamental aspects of perceptual coding of audio and video signals and their practical application in MPEG are shown. A powerful error correction mechanism is vital for a broadcasting system. The lecture explains several approaches with their implications on coverage quality, transmission capacity and receiver complexity. Another chapter of the lecture adresses the pitfalls of the mobile transmission channel. Using the example of COFDM we show how they can be overcome. In particular the manifold possibilities for configuration of this modulation method are shown. Another topic of the lecture is coverage planning, whereas the focus lays on single frequency networks. The complex concept of coverage is discussed introducing the statistical properties of the transmission path. The interaction of the concepts and their implications to practice is shown on the basis of selected broadcasting systems. The concept of multiplexing is considered. The introduction of digital broadcasting systems is special challenge. With practical examples several scenarios are shown considering the implications of economical, legal an political constraints. Finally the advantages and disadvantages of terrestrial broadcasting systems with respect to broadcasting via cable, satellite, mobile radio and the internet are discussed.

The lecturer reserves the right to alter the contents of the course without prior notification.

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Lecture notes	Material to the lecture can be found online at www.ihe.kit.edu.
Language	German
Examination	Oral (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found at the internet page of the IHE (www.ihe.kit.edu).

Course name	**Industrial Microwave and Materials Processing Technology**
Course code	**23445**
Lecturer/ Institute	Dr. habil. Feher / IHE
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic lectures on Electrical Engineering and HF-technology
Objectives	The goal is to relay theoretical and applied fundamentals with industrial background
Brief description course	Focuses of the lecture are formal, methodical, mathematical and electrotechnical fundamentals for the design and built up of energy efficient microwave systems. Detailed themes in materials science connecting the electromagnetic action by exposition to microwaves from the microscopic level to the thermal equilibrium are pointed out. Model extensions of Maxwell´s equations with basic methods of quantum theory are opposed. In the main focus of material science relevant materials and their fields of application for aerospace, automotive and chemical industry as well their manufacturing processes are conveyed.
Contents	Lecture The lecture gives at first an introduction on the special field “Industrial Microwave Technology”. By this the fundamentals of electromagnetic waves, technical frequency bands and power levels as well as the related microwave measurement technology are presented. Afterwards industrial applications are treated for aerospace, automotive, CFRP lightweight structural design and processing, food preparation, wood processing, conventional thermal processing and industrial ovens as the novel HEPHAISTOS-technology that is based on microwaves. The unique advantages of microwave processes can be clearly relayed on these examples. To describe the important material science fundamentals and their regularities the structure of technical materials for industrial processing like ceramics and sintering, metals and alloys, organic materials (polymers and laminates) and their synthesis are considered individually. Thereby also relevant themes like reaction kinetics, laws for ideal and non-ideal gases, polymerization, plastics and composites, as well as their mechanical material properties and related testing procedures are described. Another chapter considers the coupling of microwaves as the centre topic of dielectric heating. By this the Debye theory, classical polarization methods, The lecturer reserves the right to alter the contents of the course without prior notification. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The lecture is accompanied by the book published in Springer Verlag „Energy efficient Microwave Systems“ (ISBN: 978-3-540-92121-9). Material to the lecture can be found online at www.ihe.kit.edu.
Language	German
Examination	Oral (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

General remarks	Current information can be found at the internet page of the IHE (www.ihe.kit.edu).

Course name	**Advanced Radio Communications I**
Course code	**23447**
Associated Exercise	23449
Lecturer/ Institute	Dr. Younis / IHE
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic knowledge of physics, electromagnetic waves and communication systems
Objectives	At the end of the course the students will know the components of communication systems and understand the interaction between the physical phenomena and the system. The knowledge given in the lecture is sufficient to allow proceeding for an in-depth lecture/thesis on any of the topics covered in the lecture.
Brief description course	The course gives a general overview of radio communication system. Further it covers and describes in detail the parts of a communication system between (and including) the transmit/receive antennas up to the receiver. The emphasis is on a description of the physical phenomena and their influence on communication systems. In addition several practical engineering topics are addressed and their influence on communication systems is explained.
Brief description exercises	The tutorial is closely related to the lecture with exercises serving to foster the knowledge of the lecture but also to give more detailed discussion of the lecture topics.
Contents	Introduction to Wireless Communication Systems - the spread of wireless communication systems - elements of wireless communication systems Antennas - radiation mechanism of antennas - field regions - antenna parameters - antenna arrays Radio Wave Propagation Fundamentals - free-space propagation model - the basic propagation mechanisms - multipath and spatial interference pattern Time and Frequency Selective Radio Channel - introduction to small-scale fading - distribution of the receive signal strength - channel transfer function and impulse response - characterization of the frequency-selective channel - characterization of the time-variant channel Noise in Communication Systems - statistical description of signals - system noise - naturally occurring noise - oscillator phase noise - quantization and clipping noise Noise Applications - noise in cascaded systems

- microwave receiver noise temperature

The lecturer reserves the right to alter the contents of the course without prior notification.

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Lecture notes	Material to the lecture can be found online at www.ihe.kit.edu.
Language	English
Examination	Written (see current document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture
General remarks	Current information can be found at the webpage of the IHE (www.ihe.kit.edu).

Course name	
Course code	**23448**
Lecturer/ Institute	Prof. Süß / IHE
Credit Points	1,5
Semester hours	1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	Fundamentals of passive microwave sensing, applications of microwave radiometry on ground based, air and space borne platforms; presentation of modern methods in security applications.
Brief description course	Microwave radiometry is the measurement of the natural, thermal, electromagnetic radiation of our environment. Is is based on the atomic and molecular transitions of the matter with a physical temperature above 0 K. It appears as an unpolarized, stochastic broadband radiation (noise), and is dependent on the chemical/physical composition of the objects of interest, of their surface properties, the frequency, polarisation and of the absolute physical temperature. Microwave radiometry is the logic continuation of the photography at optical wavelengths and of the infrared radiometry. The lecture is interdisciplinary and describes the complete system change of the microwave radiometry for ground based, air- and space borne platforms. The lecture has an interdisciplinary character and teaches the complete microwave radiometer system chain (radiation properties of the target – propagation medium – sensor technology – data analysis) on ground based, iar and space borne platforms.
Brief description exercises	no
Contents	The focal points of the lecture are: Propagation of electromagnetic waves Radiation properties of matter and radiation laws Description of radiometers Measurements and technologies Imaging line scanners Aperture synthesis radiometer Fully polarimetric radiometers Application examples for imaging of the earth surface, oil spill detection, imaging of infrastructures Detection of hidden objects e.g. anti-personal-mines, weapons and explosives The lecturer reserves the right to alter the contents of the course without prior notification. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The notes will be distributed before the lectures Literature: B. Vowinkel „Passive Mikrowellenradiometrie“ Vieweg-Verlag F.T. Ulaby, et al „Microwave Remote Sensing“ Vol 1
Language	German

Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Actual information can be found at the internet page of the IHE (www.ihe.kit.edu).

Course name	**Optical Receiver and Bit Error Probability**
Course code	**23462**
Associated Exercise	23463
Lecturer/ Institute	Prof. Freude / IPQ
Credit Points	4,5 + 3
Semester hours	3 + 2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	pn-junction physics
Objectives	Understanding the physics of pin photodiodes and avalanche photodiodes, their nose properties, the noise of optical receivers and their bit error probability.
Brief description course	The lecture describes the characteristics of optical receivers. It covers photodetectors, the influence of noise on optical receiver, and different types of detection with and without optical amplifier. For additive Gaussian noise the bit error probability of digital optical receivers is computed.
Brief description exercises	The exercises apply the lecture's material to practical problems for providing a deeper understanding. The exercises may be electronically downloaded prior to the tutorial.

Contents

Lecture

The course concentrates ¾ after a brief introduction to optical communication systems ¾ on pin and avalamche photodiodes, noise in optical receivers, receiver limits and detection errors. The lecture addresses students of Electrical Engineering and Physics. While formulae and their derivation are definitely needed for explaining the function of devices, the emphasis is on a physical understanding.

The topics covered are:
Introduction (The nature of light. Communication with light)
Photodetectors
Fundamentals (Static PD characteristics and equivalent circuit. Basic function. Basic equations. Short-circuit photocurrent. Materials) ¾ pin photodiode (Dynamics. Cutoff frequency. Quantum efficiency. Device structures) ¾ Avalanche photodiode (DC operation of avalanche region. Quasi-stationary solution for avalanche region. Instationary solution for avalanche region. Combined reaction of absorption and avalanche region. Device structures)

Noise
Noise mechanisms (Photodetector. Generating functions. Probability density functions. Calculation of charge carrier distributions. Photo current. Instationary noise. Exces nois factor) ¾ Thermal noise ¾ Electronic amplifier noise ¾ Optical amplifier noise

Receivers and detection errors
Direct reception (Analogue reception. Digital reception. Detection errors through noise. Limits of detection) ¾ Direct, heterodyne and homodyne reception compared (Recption without optical amplifier. Reception with optical amplifier) ¾ Calculation of direct rreceiver (Analogue receiver. Digital receiver)

Exercises

The exercises apply the lecture's material to practical problems for providing a deeper understanding. The exercises may be electronically downloaded prior to the exercise.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material (a complete German compuscript as well as the German PowerPoint pages presented during the lecture) can be downloaded from http://www.ipq.kit.edu <Lectures>. Further material for the interested ones (in German): Grau, G.; Freude, W.: Optische Nachrichtentechnik (Optical communications), 3. Ed. Berlin: Springer Verlag 1991. Since 1997 out of print. Corrected reprint from University Karlsruhe 2005, available via W. F. (W.Freude@ipq.uni-karlsruhe.de).
Language	German
Examination	Oral (see actual document "Studienplan" and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination.
Course form	Lecture and Exercises
General remarks	Current information are available on the IPQ webpage (www.ipq.kit.edu).

Course name	**Optical Waveguides and Senders**
Course code	**23464**
Associated Exercise	23465
Lecturer/ Institute	Prof. Freude / IPQ
Credit Points	4,5 + 3
Semester hours	3 + 2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fundamentals of wave propagation, pn-junction physics
Objectives	Understanding the physics of basic components for optical communication
Brief description course	Two basic components of optical communication systems are treated, waveguides and senders. Beginning with fundamentals of wave propagation, the physics of waveguides and their applications are explained. The course then turns to light sources and describes the structure of LED and laser diodes as well as their spectral and dynamical properties.
Brief description exercises	The exercises apply the lecture's material to practical problems for providing a deeper understanding. The exercises may be electronically downloaded prior to the tutorial.

Contents

Lecture

The course concentrates ¾ after a brief introduction to optical communication systems ¾ on the two basic components, namely optical waveguide and transmitters (senders). The lecture addresses students of Electrical Engineering and Physics. While formulae and their derivation are definitely needed for explaining the function of devices, the emphasis is on a physical understanding.

The topics covered are:
Introduction (The nature of light. Communication with light)
Light Waveguides
Fundamentals of wave propagation (Medium properties. Kramers-Kronig relation. Wave equation and solution in homogeneous medium. Monochromatic waves. Phase and group velocity. Properties of silica glass. Attenuation. Scattering. Absorption. Dispersion) ¾ Plane boundary ¾ Principles of waveguiding ¾ Slab waveguides (Eigenvalues in pictures. Eigenvalue equation. Vector and scalar solution. Modal cutoff. Group delay dispersion. Transmission speed. Bends. Directional coupler. Y-branch) ¾ Strip waveguides ¾ Fibre waveguides (Modal fields. Weakly guiding fibre. Step-index fibre. Conventional, dispersion shifted, dispersion-compensating and dispersion flattened fibre. Parabolic-index fibre. Mode orthogonality. Coupling efficiency) ¾ Intensity modulation (Gaussian impulse. Light source. Impulse response. Transfer function. Noise-free light source. Gaussian beam. Noisy light source. Chirp-free input impulse. Sinusoidal modulation. Multimode waveguides. Mode coupling) ¾ Singlemode fibre data

Light sources

	Counting of modes ¾ Luminescence and laser radiation (Lifetime. Linewidth. Laser action. Laser active materials. Two, three-level and four-level systems.Semiconductors. Compound semiconductors) ¾ Semiconductor physics (Energy bands. Density of states. Filling of electronic states. Impurities. Doping. Heterojunctions. Band diagram for heterostructures. Emission and absorption of light. Induced and spontaneous transitions. Optical amplification. Radiative and nonradiative transitions) ¾ Light-emitting diode (Output power. Modulation properties. Devices. Surface emitter. Edge emitter. Superluminescent diode. LED spectrum) ¾ Laser diode (Basic relations. Rate equations. Threshold current. Normalized rate equations. Characteristic curves. Powers and Efficiencies. Small-signal and large-signal intensity modulation. Amplitude-phase coupling. LD spectrum. Devices. Gain-guided lasers. Index-guided laser. DFB-Laser. VCSEL) Optical amplifiers Semiconductor amplifier (Fabry-Perot amplifier. Travelling-wave amplifier) ¾ Doped fibre amplifier ¾ Optical amplifier noise (Noise figure) Supplementary material Summaries, problems and quizzes ¾ Solutions to problems and quizzes Exercises The exercises apply the lecture’s material to practical problems for providing a deeper understanding. The exercises may be electronically downloaded prior to the exercise. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material (a complete English compuscript, supplemented with summaries, problems, quizzes and solutions, as well as the English PowerPoint pages presented during the lecture) can be downloaded from http://www.ipq.kit.edu <Lectures>. Further material for the interested ones (in German): Grau, G.; Freude, W.: Optische Nachrichtentechnik (Optical communications), 3. Ed. Berlin: Springer Verlag 1991. Since 1997 out of print. Corrected reprint from University Karlsruhe 2005, available via W. F. (W.Freude@ipq.uni-karlsruhe.de).
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture and Exercises
General remarks	Current information are available on the IPQ webpage (www.ipq.kit.edu).

Course name	**Field Propagation and Coherence**
Course code	**23466**
Associated Exercise	23467
Lecturer/ Institute	Prof. Freude / IPQ
Credit Points	4,5 + 3
Semester hours	3 + 2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fundamentals of wave propagation
Objectives	Propagation of optical fields in multimode fibres and in a homogeneous medium. Coherence properties of optical fields and measurement techniques.
Brief description course	Multimode fibres became increasingly important in recent times, if price matters and not the maximum transmission capacity. The description of multimode fibre transmission, the wave propagation in homogeneous media and the description and measurement of coherence of optical fields is the topic of this lecture.
Brief description exercises	The exercises apply the lecture's material to practical problems for providing a deeper understanding. The exercises may be electronically downloaded prior to the tutorial.
Contents	Lecture Multimode waveguides (Introduction. Refractive index profile. Fibre data. Group delay dispersion) ¾ Waves and modes (LPnm-modes. Parabolic profile) ¾ Rays and modes (Free-space longitudinal and transverse modes. Sampling theorem. Phase space. Ray optics. Asymptotic approximations. JWKB approximation. Types of rays. Ray equation. Counting of modes. Excitation of modes. Excitation with light rays. Radiation of modes. Practical pencil of rays. Graded-index lens) ¾ Near-field and far-field ¾ Group delay dispersion (Group delay. Profile optimization) ¾ Impulse response (Transfer function. Singlemode impulse response. Singlemode power impulse response. Multimode power impulse response. Group delay power transfer function) ¾ Fibre imperfections and mode coupling ¾ Bandwidth-length product ¾.Coupling devices (Light sources and fibres. Butt coupling. 70-%-excitation) ¾ Optical branches (Multimode interference (MMI) coupler. Directional coupler) ¾ Modal noise Propagation of optical fields Solution of wave equation (Rayleigh-Sommerfeld and Helmholtz-Kirchhoff integrals. Boundary field and field gradient impulse response and convolution. Fourier, Fresnel and Fraunhofer approximation) ¾ Uniqueness of Helmholtz equation ¾ Paraxial optics (Gauss-Laguerre fields. Gaussian beam and spherical resonators. ABCD matrix) Coherence of optical fields

	Analytic optical signals ¾ Coherence function and power spectrum (Ergodic signals. Principle of a measurement. Temporal and spatial coherence. Spectrally pure process. Propagation of mutual coherence. Coherence tensor. Higher-order coherence functions) ¾ Polarisation (Coherence matrix. Stokes parameter. Jones vectors and matrices. Poincaré sphere. Eigenstates and principal states. Polarisation mode dispersion and birefringence) ¾ Interference (Baseband spectrum, contrast and line shapes. Narrowband and broadband sources. Mach-Zehnder and Michelson interferometer. Source with a comb spectrum. Multipath interference with dispersive waveguides) ¾ Interference of waves with different frequencies (Photocurrent. Correlation analysis of photocurrent. Thermal light source. Laser light source. Influence of polarisation) Exercises The exercises apply the lecture's material to practical problems for providing a deeper understanding. The exercises may be electronically downloaded prior to the exercise. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material (a complete German compuscript with English captions as well as the English PowerPoint pages presented during the lecture) can be downloaded from http://www.ipq.kit.edu <Lectures>. Further material for the interested ones (in German): Grau, G.; Freude, W.: Optische Nachrichtentechnik (Optical communications), 3. Ed. Berlin: Springer Verlag 1991. Since 1997 out of print. Corrected reprint from University Karlsruhe 2005, available via W. F. (W.Freude@ipq.uni-karlsruhe.de). Freude, W.: Vielmodenfasern. 50 Seiten in: Voges, E.; Petermann, K. (Eds.), Handbuch der optischen Kommunikationstechnik (Handbook of optical communications). Springer-Verlag, Berlin 2002
Language	English
Examination	Oral (see actual document "Studienplan" and notice of the examination office ETIT)
Formation of grade	Grades result from the oral examination.
Course form	Lecture and Exercises
General remarks	Current information are available on the IPQ webpage (www.ipq.kit.edu).

Course name	**Selected Topics in MicrowaveTechnology**
Course code	**23470**
Associated Exercise	None
Lecturer/ Institute	Prof. Freude / IPQ and Prof. Thumm / IHE
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Principles of Microwave Technology
Objectives	The goal is to relay fundamentals of noise in communication systems, and an understanding of basic components, methods and systems of microwave engineering at high power levels as well as their various applications.
Brief description course	The two lecture parts "Noise" (Prof. Freude) and "High Power Microwave Engineering" (Prof. Thumm) explain on the one hand the description and measurement of the limiting sensitivity of noisy communication receivers, on the other hand the design and applications of mciro and milllimeterwave tubes as well as wave propagation and mode conversion in multimode hollow waveguides.
Brief description exercises	none
Contents	The course aims at providing deeper knowledge in special areas of microwave technology. The lecture consists of the two parts "Noise" and "High-Power Microwave Engineering". The choice of these very areas emphasizes two extreme aspects of microwave technology, namely the detection of very small communication signals where the limiting factor is noise, and the generation of high-power micro and millimetre waves. Part 1: Noise (Prof. Freude) With "noise" one associates at first a random acoustical phenomenon, e. g., as produced by turbulently streaming water. Such random signals can be also generated electrically. Examples are interstation noise produced by a radio receiver when wrongly tuned in-between stations, or heat and light radiation, which humans can perceive with sense organs in skin and eye, respectively. For the reception of very small signals, the limiting factor is noise. Its description and calculation is relevant for the whole frequency spectrum that is utilized for information transmission, starting from low radio frequencies up to the range of photonic communication. The topics covered are: Noise in analogue and digital systems ¾ Mathematical tools ¾ Narrowband noise ¾ Detection of noisy signals ¾ Physical sources of noise ¾ Shot noise ¾ Johnson noise ¾ Noise in optical detection ¾ Noise of one-ports and two-ports ¾ Measuring noise ¾ Noise in semiconductor diodes ¾ Noise in bipolar transistors Part 2 : High Power Microwave Engineering (Prof. Thumm) The generation of high-power microwaves is important for radio broadcast stations, heating of nuclear fusion plasmas, materials processing and particle accelerators, and such leads to heavy machinery construction. An important applications in everyday's life are microwave ovens. Overmoded metallic waveguides, which are used for micro and millimeterwave energy transport, have much in common to optical multimode waveguides. An introduction compares the state-of-the-art design as well as important applications of semiconductor microwave power sources and microwave tubes.

	The topics covered are: Vacuum electron devices for microwaves (klystrons, travelling wave tubes, magnetrons, gyrotrons, free electron laser/maser) ¾ Modes in oversized hollow waveguides ¾ Mode converters ¾ Quasi-optical transmission ¾ Applications (gyrotron oscillators for generation and heating of magnetically confined nuclear fusion plasmas, active diagnostics of nuclear fusion plasmas, electron cyclotron resonance ion sources (ECRIS), X-ray sources, materials processing, electron spin resonance (ESR) spectroscopy, millimetre-wave radar for atmospheric and planetary remote sensing, deep space and satellite communications, drivers for next-generation high gradient linear RF electron super colliders) The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The lecture material can be downloaded as pdf-files (Noise compuscript and slides) or are handed out in class as a script with additional single handouts.
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT)
Formation of grade	Grades result from the oral examination
Course form	Lecture with exercises
General remarks	The course consists of two lecture blocks. Current information can be found on the IPQ website (www.ipq.kit.edu).

Course name	**Einführung in die Quantentheorie für Elektrotechniker mit Übungen**
Course code	**23474**
Lecturer/ Institute	Prof. Grau / IPQ
Credit Points	3
Semester hours	3
Term	Bachelor/Master
Compulsory course	Bachelor/Master
Prerequisites	none
Brief description course	Introduction to theory including latest developments
Brief description exercises	Examples illustrate use of theoretical considerations
Contents	Duality wave/particle Dirac´s bracket formalism Probabilities, expectation values Uncertainty relations, complementarity Spooky action at a distance, entangled states Quantization of systems The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Script as pdf-file for download
Language	German, if majority wishes also in english
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Course form	Lecture
General remarks	Current information can be found on the IPQ (http://www.ihq.uni-karlsruhe.de/index_en.htm) webpage.

Course name	**Quantum Functional Devices and Semiconductor Technology**
Course code	**23476**
Lecturer/ Institute	Dr. Walther/ IPQ
Credit Points	3
Semester hours	2
Term	Bachelor/Master
Compulsory course	Bachelor/Master
Prerequisites	none
Objectives	Basics of quantum effect devices
Brief description course	Quantum effects in semiconductors and quantum functional devices (transistors, lasers and detectors) as well as device fabrication technology.
Brief description exercises	.
Contents	Fundamental properties of quantum functional devicesHeterostructures and band gap engineering Carrier confinement in 2-, 1- and 0-dim structures Quantum functional compound semiconductor devices High electron mobility transistors Quantum well, quantum dot and quantum cascade lasers Infrared detectors Single photon devices for quantum cryptography Compound semiconductor technology Epitaxy, lithography, etching and deposition Future trends in microelectronics Scaling limits, Moore‘s law, devices beyond Moore The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German or English
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Course form	Lecture,
General remarks	Current information can be found on the IPQ (http://www.ihq.uni-karlsruhe.de/index_en.htm) webpage.

Course name	**Laser Metrology I**
Course code	**23478**
Lecturer/ Institute	Prof. Hugenschmidt/ IPQ
Credit Points	3
Semester hours	2
Term	Winter-/ Summer-term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	The lecture comprises mathematical background as well as technical and research related experimental applications. Examples are described making use of cw-lasers and pulsed lasers. With ultra-short pulses (few ps to fs) new nonlinear optical laser diagnostic schemes are increasingly developed and used which are also included and discussed in detail.
Brief description exercises	.

Contents

The lecture, “Laser Metrology I and II” presented in 2 subsequent semesters is dealing both with the many-sided practical applications and underlying theories. Both parts are organized autonomously so that students may either start with part I or with part II, respectively.
Laser Metrology I:
Laser beam radiation characteristics, theory and experimental possibilities for measuring coherence properties.

Specific lasers used for metrological tasks. Dielectric solid state lasers, semiconductor lasers, dye lasers, gas laser and metal-vapour-lasers.

Metrological information (amplitude, phase, polarization, frequency) as deducible from laser propagation in homogeneous, inhomogeneous, isotropic non-isotropic transparent materials.

Photographic and photoelectric laser recording methods including sensor arrays (CCD, CMOS) for numerical image treatment and quantitative evaluation of metrological information.

Evaluation of laser-photographic or cinematographic high-speed recording methods for investigations of rapid, transient phenomena. Minimization of speckle effects, (reduction of spatial noise). Optimization of speckles for improving metrological information contents by novel laser carrier frequency recording techniques.

Laser interferometry, two-beam and multi-beam (Fabry-Perot) techniques for sensitive phase measurements. Multiwavelengths interferometry and numerical evaluation capabilities. Examples are given concerning studies in plasma physics. Laser gyroscopes based on the Sagnac effect.

Moiré diagnostic techniques for quantitative measurements of laser beam deflection caused by refractive index gradients of phase objects (schlieren effect).

Ultra-short pulsed laser diagnostics. Theoretical background concerning generation and measurement of mode locked pulses. Experimental realizations and devices used for high-speed photography and spectroscopy of transient phenomena (pump- and probe-techniques).

	Outlook: XUV-pulse technology aimed at achieving sub-femtosecond temporal resolutions down to the attosecond range (1 as = 10-18 s). Laser Metrology II: Special coherence requirements for holographic applications. (spectrum, frequency chirp). Discussion of measures in order to influence coherence properties (mode selection). Holography, historical development, Gabors “inline” holography and “off-axis” holography according to Leith and Upatnieks. Mathematical description and experimental approach related to optical wave front recording and reconstruction. Quantitative evaluation of holographically stored information. Fresnel-, Fraunhofer and Fourier-type of holography. Optical pattern recognition. Laser range finders, recent developments. Comparison of pulsed laser time of flight methods and cw laser modulation techniques. Improved performance by heterodyne detection and tomoscopic gating techniques. Laser velocity measurements based on the Doppler-effect. Laser radar as used for traffic control and other technical applications. Laser anemometers for fluid dynamic studies as well as for medical applications. Laser absorption and scattering techniques for particle density measurements in environmental diagnostics. LIDAR techniques using Rayleigh-, Brillouin- or Raman-scattering processes. Outlook: Improvements - compared to spontaneous scattering - caused by stimulated scattering due to optical nonlinearities (based on the availability of ultra short mode-locked laser pulses) and many-sided applications in industrial techniques and fundamental research. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Book and Textbook: Lasermesstechnik, Diagnostik der Kurzzeitphysik“, M. Hugenschmidt, Springer Verlag, 2006, ISBN-10 3-540-29920-3, ISBN-13 978-3-540-29920-2
Language	German or English, depending on participating students
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture,
General remarks	Current information can be found on the IPQ (http://www.ihq.uni-karlsruhe.de/index_en.htm) webpage.

Course name	**Laser Metrology II**
Course code	**23479**
Lecturer/ Institute	Prof. Hugenschmidt/ IPQ
Credit Points	3
Semester hours	2
Term	Winter-/ Summer-term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	The lecture comprises mathematical background as well as technical and research related experimental applications. Examples are described making use of cw-lasers and pulsed lasers. With ultra-short pulses (few ps to fs) new nonlinear optical laser diagnostic schemes are increasingly developed and used which are also included and discussed in detail.
Brief description exercises	.
Contents	The lecture, “Laser Metrology I and II” presented in 2 subsequent semesters is dealing both with the many-sided practical applications and underlying theories. Both parts are organized autonomously so that students may either start with part I or with part II, respectively. Laser Metrology I: Laser beam radiation characteristics, theory and experimental possibilities for measuring coherence properties. Specific lasers used for metrological tasks. Dielectric solid state lasers, semiconductor lasers, dye lasers, gas laser and metal-vapour-lasers. Metrological information (amplitude, phase, polarization, frequency) as deducible from laser propagation in homogeneous, inhomogeneous, isotropic non-isotropic transparent materials. Photographic and photoelectric laser recording methods including sensor arrays (CCD, CMOS) for numerical image treatment and quantitative evaluation of metrological information. Evaluation of laser-photographic or cinematographic high-speed recording methods for investigations of rapid, transient phenomena. Minimization of speckle-effects, (reduction of spatial noise). Optimization of speckles for improving metrological information contents by novel laser carrier frequency recording techniques. Laser interferometry, two-beam and multi-beam (Fabry-Perot) techniques for sensitive phase measurements. Multiwavelengths interferometry and numerical evaluation capabilities. Examples are given concerning studies in plasma physics. Laser gyroscopes based on the Sagnac effect. Moiré diagnostic techniques for quantitative measurements of laser beam deflection caused by refractive index gradients of phase objects (schlieren effect). Ultra-short pulsed laser diagnostics. Theoretical background concerning generation and measurement of mode locked pulses. Experimental realizations and devices used for high-speed photography and spectroscopy of transient phenomena (pump- and probe-techniques).

	Outlook: XUV-pulse technology aimed at achieving sub-femtosecond temporal resolutions down to the attosecond range (1 as = 10-18 s). Laser Metrology II: Special coherence requirements for holographic applications. (spectrum, frequency chirp). Discussion of measures in order to influence coherence properties (mode selection). Holography, historical development, Gabors “inline” holography and “off-axis” holography according to Leith and Upatnieks. Mathematical description and experimental approach related to optical wave front recording and reconstruction. Quantitative evaluation of holographically stored information. Fresnel-, Fraunhofer and Fourier-type of holography. Optical pattern recognition. Laser range finders, recent developments. Comparison of pulsed laser time of flight methods and cw laser modulation techniques. Improved performance by heterodyne detection and tomoscopic gating techniques. Laser velocity measurements based on the Doppler-effect. Laser radar as used for traffic control and other technical applications. Laser anemometers for fluid dynamic studies as well as for medical applications. Laser absorption and scattering techniques for particle density measurements in environmental diagnostics. LIDAR techniques using Rayleigh-, Brillouin- or Raman-scattering processes. Outlook: Improvements - compared to spontaneous scattering - caused by stimulated scattering due to optical nonlinearities (based on the availability of ultra short mode-locked laser pulses) and many-sided applications in industrial techniques and fundamental research. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Book and Textbook: Lasermesstechnik, Diagnostik der Kurzzeitphysik“, M. Hugenschmidt, Springer Verlag, 2006, ISBN-10 3-540-29920-3, ISBN-13 978-3-540-29920-2
Language	German or English, depending on participating students
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture,
General remarks	Current information can be found on the IPQ (http://www.ihq.uni-karlsruhe.de/index_en.htm) webpage.

Course name	**Laser physics**
Course code	**23480**
Associated Exercise	23481
Lecturer/ Institute	Dr. Eichhorn/ IPQ
Credit Points	3 + 1.5
Semester hours	2 + 1
Term	Bachelor/Master
Compulsory course	Bachelor/Master
Prerequisites	none
Objectives	The goal is to relay experimental and theoretical fundamentals.
Brief description course	The lecture adresses the fundamental physics lasers, the basic processes of light amplification and the formalisms necessary to describe lasers and laser resonators. The generation of laser pulses and various laser architectures and realizations is presented in detail.
Brief description exercises	The tutorial focuses on the topics of description of lasers, their theoretical background and the layout of various laser designs. Problems and exercises are handed out after each lecture and are to be solved for the next tutorial, in which their solutions will be presented in detail.
Contents	The content of the lecture is summarized as follows: 1 Quantum-mechanical fundamentals of lasers 1.1 Einstein relations and Planck's law 1.2 Transition probabilities and matrix elements 1.3 Mode structure of space and the origin of spontaneous emission 1.4 Cross sections and broadening of spectral lines 2 The laser principle 2.1 Population inversion and feedback 2.2 Spectroscopic laser rate equations 2.3 Potential model of the laser 3 Optical Resonators 3.1 Linear resonators and stability criterion 3.2 Mode structure and intensity distribution 3.3 Line width of the laser emission 4 Generation of short and ultra-short pulses 4.1 Basics of Q-switching 4.2 Basics of mode locking and ultra-short pulses 5 Laser examples and their applications 5.1 Gas lasers: The Helium-Neon-Laser 5.2 Solid-state lasers 5.3 Special realizations of lasers The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Lecture-accompanying scriptum
Language	English
Examination	Oral (see actual document "Studienplan" and notice of the examination office ETIT).
Formation of grade	Grades result from the oral exam
Course form	Lecture, Exercises and Tutorial
General remarks	The course comprises of the interleaved lecture blocks, exercises, and tutorials. Current information can be found on the IPQ (http://www.ihq.uni-karlsruhe.de/index_en.htm) webpage.

Course name	**Optoelectronic Components**
Course code	**23486**
Associated Exercise	23487
Lecturer/ Institute	Prof. Freude / IPQ
Credit Points	4,5 + 3
Semester hours	3 + 2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fundamentals of wave propagation, pn-junction physics
Objectives	Understanding the physics of most important components for optical communication
Brief description course	Fundamentals and applications of integrated optical waveguides and optical fibres, of light sources like lasers and LED, of pin-photodetectors and of optical receivers are explained.
Brief description exercises	The exercises apply the lecture’s material to practical problems for providing a deeper understanding. The exercises may be electronically downloaded prior to the exercise.

Contents

Lecture

The course concentrates ¾ after a brief introduction to optical communication systems ¾ on basic opto-electronic communication components, namely on optical waveguides, semiconductor light sources, optical amplifiers, pin photodiodes, noise in optical receivers, receiver limits and detection errors. The lecture addresses students of Electrical Engineering and Physics. While formulae and their derivation are definitely needed for explaining the function of devices, the emphasis is on a physical understanding.

The topics covered are:
Introduction (The nature of light. Communication with light)
Light Waveguides
Fundamentals of wave propagation (Medium properties. Kramers-Kronig relation. Wave equation in a homogeneous medium. Phase and group velocity. Properties of silica glass) ¾ Plane boundary ¾ Principles of waveguiding ¾ Slab waveguides (Eigenvalues in pictures. Eigenvalue equation. Vector and scalar solution. Modal cutoff. Group delay dispersion. Transmission speed. Bends. Directional coupler. Y-branch) ¾ Strip waveguides ¾ Fibre waveguides (Modal fields. Weakly guiding fibre. Step-index fibre. Conventional, dispersion shifted, dispersion-compensating and dispersion flattened fibre. Parabolic-index fibre. Mode orthogonality. Coupling efficiency) ¾ Singlemode fibre data

Light sources

	Counting of modes ¾ Luminescence and laser radiation (Lifetime. Linewidth. Laser action. Laser active materials. Semiconductors. Compound semiconductors) ¾ Semiconductor physics (Energy bands. Density of states. Filling of electronic states. Impurities. Doping. Heterojunctions. Band diagram. Emission and absorption of light. Induced and spontaneous transitions. Optical amplification. Radiative and nonradiative transitions) ¾ Light-emitting diode (Output power. Modulation properties. Devices. Surface emitter. Edge emitter. Superluminescent diode. LED spectrum) ¾ Laser diode (Basic relations. Rate equations. Threshold current. Normalized rate equations. Characteristic curves. Powers and Efficiencies. Small-signal and large-signal intensity modulation. Amplitude-phase coupling. LD spectrum. Devices. Gain-guided lasers. Index-guided laser. DFB-Laser. VCSEL) Optical amplifiers Semiconductor amplifier (Fabry-Perot amplifier. Travelling-wave amplifier) ¾ Doped fibre amplifier pin photodiode Basic equations (Short-circuit photocurrent. Equivalent electrical circuit) ¾ Materials ¾ Time and frequency response ¾ Cutoff frequency, quantum efficiency and responsivity ¾ Device structures Noise Noise mechanisms ¾ Photocurrent noise ¾ Thermal noise ¾ Electronic amplifier noise ¾ Optical amplifier noise Receivers and detection errors Pin photodiode receiver limits ¾ Detection errors Supplementary material Summaries, problems and quizzes ¾ Solutions to problems and quizzes Exercises The exercises apply the lecture's material to practical problems for providing a deeper understanding. The exercises may be electronically downloaded prior to the exercise. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material (a complete English compuscript, supplemented with summaries, problems, quizzes and solutions, as well as the English PowerPoint pages presented during the lecture) can be downloaded from http://www.ipq.kit.edu <Lectures>. Further material for the interested ones (in German): Grau, G.; Freude, W.: Optische Nachrichtentechnik (Optical communications), 3. Ed. Berlin: Springer Verlag 1991. Since 1997 out of print. Corrected reprint from University Karlsruhe 2005, available via W. F. (W.Freude@ipq.uni-karlsruhe.de)
Language	English
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT)
Formation of grade	Grades result from the oral examination.
Course form	Lecture and Exercises
General remarks	Current information are available on the IPQ webpage (www.ipq.kit.edu).

Course name	**Probability Theory**
Course code	**23505**
Associated Exercise	23507
Lecturer/ Institute	Prof. Dr. Jondral / CEL
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Mathematics I and II, Fourier Transform
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	Fundamental lecture on probability theory. This lectures gives an introduction to the fields of probability and stochastic processes. It makes basic knowledge available that is needed to understand continuative lectures.
Brief description exercises	In addition to the lectures, exercises have to be solved. Problems as well as methods to find their solutions are discussed biweekly in the lecture hall.
Contents	Lecture The daily work of a modern engineer, especially in the field of communications, calls for a sound fundamental knowledge of stochastics. This lecture on probability theory introduces the students of electrical engineering and information technology to this domain. The lecture is organized as follows: First the notions probability space, conditional probability as well as random variable are thoroughly defined. After highlighting the parameters of random variables, the most important probability distributions are discussed. The chapter on multidimensional random variables particularly covers correlation coefficients and functions of multidimensional random variables. One chapter is devoted to the laws of large numbers and to the central limit theorem. The chapters on basics of stochastic processes and on special stochastic processes make the lecture's content perfect. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Friedrich K. Jondral, Anne Wiesler: Wahrscheinlichkeitsrechnung und stochastische Prozesse - Grundlagen für Ingenieure und Naturwissenschaftler. 2. Auflage, Stuttgart, Leipzig, Wiesbaden 2002: B.G. Teubner, ISBN 3-519-16263-6
Language	German
Examination	Written (see actual document "Studienplan" and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture accompanied by exercises
General remarks	The lecturer reserves the right to alter the contents of the course without prior notification.

Course name	**Communications Engineering I**
Course code	**23506**
Associated Exercise	23508
Lecturer/ Institute	Prof. Dr. Jondral / CEL
Credit Points	4,5 + 1,5
Semester hours	3 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Mathematics I – III, Probability Theory, Signals and Systems
Objectives	Introduction to basics, methods and applications of communications components and systems
Brief description course	Fundamental lecture on communications. First the theoretical foundations of communications are glanced at, then essential components and systems are reviewed.
Brief description exercises	In addition to the lectures, exercises have to be solved. Problems as well as methods to find their solutions are discussed biweekly in the lecture hall.

Contents

This lecture provides an introduction to communications based on mathematics and systems theory.

The first chapter covers signals and systems in the complex baseband. It is shown that essential portions of signal processing may be performed at the equivalent lowpass representation (which is in most cases efficient in terms of computing effort). The second chapter introduces basic notations of Shannon's information theory. Here, specific attention is given to the definitions of *information* and *channel capacity*. The third chapter is on transmission channels in mobile communication.

The fourth chapter introduces to the problem of source coding and demonstrates facsimile transmission as a practical application. Chapters five and six are on channel (forward error correction) coding. After general comments on channel coding, the first part of this presentation deals with block codes whereas in the second part convolutional coding is discussed together with the Viterbi-algorithm as the fundamental decoding method.

The most popular modulations modes are treated in chapter seven. The introduction of phase shift keying (PSK) as well as of minimum shift keying are on focus here. A section on multicarrier transmission is integrated in order to underline the increasing acceptation of this technology in broadcast, wireless local area networks and mobile communications. Chapter eight considers the foundations of decision theory like it is applied signal detection in Radar or for demodulation in communications. Demodulators are on focus too in the ninth chapter. Here, special attention is given to PSK and MSK again.

Chapter ten points out the compromises a system's developer has to respond to when working on practical problems. Shannon's limit, that gives the maximum symbol rate up to which in principle a transmission is possible with arbitrary low error rate, as well as bandwidth efficiency, an effective quality criterion for transmission with respect to licensing costs are discussed. Chapter eleven is on multiple input multiple output (MIMO). MIMO methods provide a means for increasing the capacity in mobile networks. They play a prominent role in communications research over the last couple of years. Now, they are about to be introduced into practical applications. Chapter twelve covers the basic schemes of frequency division multiple access (FDMA), time division multiple access (TDMA) and code division multiple access (CDMA).

Chapters 13 and 14 pick up the areas of synchronization and channel equalization that are essential for almost every receiver. Chapter 15 provides a short overview over networking with special emphasis on the open systems interconnection (OSI) layered model for communications. The last three chapters successively introduced the global system for mobile communications (GSM), the universal mobile communications system (UMTS) and, representing broadcast systems based on OFDM digital audio broadcast (DAB).

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Friedrich Jondral: Nachrichtensysteme, 4. Auflage. J. Schlembach Fachverlag, Wilburgstetten, 2011, ISBN 978-3-935340-68-7 / further material may be found on the web site of the Institut für Nachrichtentechnik
Language	German
Examination	Written examination (but refer to the actual "Studienplan" and notice of the ETIT examination office).
Formation of grade	Grades result from the written examination
Course form	Lecture accompanied by exercises
General remarks	The lecturer reserves the right to alter the contents of the course without prior notification.

Course name	**Special Areas in Communications**
Course code	**23509**
Lecturer/ Institute	Prof. Dr. Jondral / INT
Credit Points	3
Semester hours	2
Term	Winter semester
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	Communications Engineering I
Objectives	The main goal of this series of lectures is to communicate basic knowledge about systems. Another important topic is the fact that a modern practically working engineer should think interdisciplinary.
Brief description course	This series of lectures is designed as an introduction to the interdisciplinary area of satellite communications and explains why apart from communications engineering knowledge about mechanics, propagation physics, antenna technology etc. are helpful to understand systems.

Contents

1. Introduction
1.1 History and development of satellite communications
1.2 The archoitecture of a SATCOM system
1.3 The ground segment
1.4 Orbits
1.5 Technological developments
1.6 The development of services
1.7 Outlook
2. Evaluation of SATCOM links: Link budgets
2.1 The most important link budget parameters
2.2 Short forms of link budgets
2.3 The carrier-to-noise ratio of a ground - satellite - ground link
3. Multiple access
3.1 Routing
3.2 The multiple access principle
3.3 Frequency division multiple access (FDMA)
3.4 Time division multiple access (TDMA)
3.5 Code multiple access (CDMA)
4. Channel allocation and access protocols
4.1 Deterministic channel allocation
4.2 Random access
5. Intersatellite links
5.1 Links between geostationary and low erarth orbiting satellites (GEO – LEO)

5.2 Links between geostationary satellites (GEO – GEO)
5.3 Links between low earth orbiting satellites
5.4 Frequencies
6. Satellites employing regenerative transponders
6.1 Comparison of link budgets
6.2 On-board processing
6.3 Impact on the ground system
6.4 Conclusions
7. Frequencies, Systems, Applications
7.1 Frequency allocations
7.2 SATCOM systems in mobile communications

	7.3 Satellite navigation (GPS and Gallileo)
Lecture notes	The figures shown during the lectures will be made available to the audience via the web site of the Communications Engineering Lab. Students are encouraged to elaborate their own lectures notes.
Language	German
Examination	Oral examination (but refer to the actual “Studienplan” and notice of the ETIT examination office).
Formation of grade	Grades result from the oral examination
Course form	Lectures
General remarks	The lectures’ contents partially reflect actual research performed at INT. The lecturer reserves the right to alter the contents of the course without prior notification.

Course name	**Software Radio**
Course code	**23510**
Lecturer/ Institute	Prof. Dr. Jondral / CEL
Credit Points	3
Semester hours	2
Term	Summer semester
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Communications Engineering I
Objectives	Extensive knowledge about mobile communications, about the appertaining standards and about recent developments in the fields of Software Defined Radio, Cognitive Radio and Cognitive Networking is presented
Brief description course	The lectures present extensive knowledge about mobile communications, about the appertaining standards and about recent developments in the fields of Software Defined Radio, Cognitive Radio and Cognitive Networking.

Contents

The lectures present extensive knowledge about mobile communications, about the appertaining standards and about recent developments in the fields of Software Defined Radio (SDR), Cognitive Radio (CR) and Cognitive Networking (CN).

Chapter one retraces the development of mobile communication systems from the fifties of the twenties century. Multiple access modes are examined with respect to the SDR paradigm. Modeling of mobile communications channels within the framework of different standards is discussed.

Chapter two covers the architecture of software radios. Here, the principles of the superhet as well as of the direct mixing (zero IF) receiver are elaborated in great detail. The most important processing component of digital radio structures is their analog-to-digital converter. These components are also extensively discussed. Moreover, starting from the application scenarios, distinctions and similarities of military and civil SDRs found.

The third chapter covers essential radio components. Following a detailed discussion of the mobile communication channel's properties, different modulation and demodulation modes are introduced. Afterwards, direct sequence spread spectrum as well as code division multiple access (CDMA) are examined. After a short review concerning channel equalization, several important channel (forward error correction) coding methods are discussed with respect to a possible unification of their signal processing. Source coding is exemplified by GSM. The chapter closes with a summary about RAKE receivers and multi user detectors.

The fourth chapter lumps together the most popular mobile communication standards. First of all, the second generation standards (DECT, GSM, IS-136, IS-95) are discussed. Then the third generation standards (cdma2000, UMTS) as well as the wireless local area network standards IEEE 802.x are introduced.

The hardware underlying a SDR or a CR is subject of chapter five. Properties of general purpose processors (GPPs), digital signal processors (DSPs) and field programmable gate arrays are extracted. Additionally, reconfigurable hardware is presented.

Chapter six explains the configuration of a SDRs. Here, special attention is paid to the simulation tools used as well as to harmonization of standards.

	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The power point presentations shown during the lectures will be available to the participants via the web site of the Institut für Nachrichtentechnik.
Language	German
Examination	Oral examination (but refer to the actual “Studienplan” and notice of the ETIT examination office).
Formation of grade	Grades result from the oral examination
Course form	Lectures
General remarks	The lectures’ contents partially reflect actual research performed at INT. The lecturer reserves the right to alter the contents of the course without prior notification.

Course name	**Communications Engineering II**
Course code	**23511**
Associated Exercise	23513
Lecturer/ Institute	Dr. Jäkel / INT
Credit Points	3+1,5
Semester hours	2+1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Communications Engineering I, System Theory
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	The lecture complements the topics discussed within the basic course Nachrichtentechnik I and System Theory. For this purpose, new perspectives are added to already known topics and problems are covered, which were not part of Nachrichtentechnik I.
Brief description exercises	To accompany the lecture material, assignments and the corresponding solutions will be given out and discussed during lecture hall exercises. The presentation is assisted by computer simulations.

Contents

The lecture Nachrichtentechnik II broadens and complements knowledge acquired in the lecture Nachrichtentechnik I. The lecture covers the following topics:

Communication basics and Transmission characteristics: This section discusses the vector representation of signals with orthogonal base functions and the transition from the base band to the band pass region. The representation is used to introduce transmission characteristics like spectrum or error probability for linear modulation techniques. Furthermore, the first and the second Nyquist criterion are discussed.

The mobile channel: Modeling of the mobile channel as well as its description within the coherence context are topics of this section. The tapped-delay-line model is introduced and common fading models like Rayleigh, Rice or Nakagami are discussed.

Equalization: This section is motivated by the signal distortion caused by the mobile channel. The functionality of the zero-forcing equalizer, the MMSE and FIR-based equalizers are analyzed.

Synchronization: A coherent transmission of data requires synchronization in the receiver. Several methods for time, frequency and phase synchronization are derived and founded on estimation theory.

Data link Control: This chapter focuses on the data link layer in the ISO/OSI model. The data flow control as well as multiplexing and access methods are discussed. Queuing theory is introduced for analysis. All methods are motivated by examples of protocols and MAC specifications.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Slides are provided. Further reading is recommended in the lecture.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).

Formation of grade	Grades result from the written examination
Course form	Lecture, Exercises

Course name	**Selected Topics in Communications**
Course code	**23512**
Lecturer/ Institute	Dr. Jäkel / INT
Credit Points	4,5
Semester hours	3
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Communications 1, Probability Theory
Objectives	The goal is to teach scientific writing and presentation
Brief description course	Working out a technical topic, writing a paper, presentation
Contents	Today, summarizing a technical content by means of a (short) paper and presenting it in front of an audience plays a crucial role in every engineer's work. The seminar aims at developing these abilities. Based on a study of existing literature, the participants have to become familiar with a given technical problem, summarize the topic in a short paper and present it to the other participants. A well structured paper is as important as well-designed slides and a competent presentation style. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	References will partially be provided and partially have to be found independently. All participants will be provided templates for both paper and presentation. Thereby, participants will learn to work with the tools LaTeX and Powerpoint, which will become important for further theses. Members of the Institut für Nachrichtentechnik instruct and support the participants throughout the seminar.
Language	German/ English
Examination	Paper, presentation (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Combination of written part (paper) and oral part (presentation)
Course form	Seminar

Course name	**Team Project Communications Engineering**
Course code	**23515**
Lecturer/ Institute	Prof. Jondral / CEL
Credit Points	6
Semester hours	4
Term	Summer term and winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	Basics of scientific work, presentation techniques, project management
Brief description course	The team project gives students the opportunity to work with other students in a development team and solve an interesting problem in communications engineering.
Contents	The topic of the team project changes every semester. It treats aspects of current research at the CEL. To structure the project, the team first develops a project plan together with the supervisors. This plan includes mile stones and project interfaces to groups inside the team. During the semester the progress of the team is presented to the supervisors and other team member. The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German or English
Examination	Project report and presentations
Formation of grade	Final project result and intermediate presentations
Course form	Team project

Course name	**Communications Systems Laboratory**
Course code	**23517**
Lecturer/ Institute	Prof. Jondral/ INT
Credit Points	6
Semester hours	4
Term	Summer Term and Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Signals and systems (SuS), communications engineering I (NT I)
Objectives	The laboratory is implemented on Linux-Workstations. It is based on the simulation tool *MatLab* of The *MathWorks* . Every experiment consists of several simulations which are to be compiled or parameterized. Moreover, the participants should comprehend and interpret the results. A booklet to write down the minutes has to be maintained.
Brief description course	The topics under consideration in this laboratory are based on the lectures SuS and NT I. The lab's main objective is to introduce fundamental knowledge about communications to the participants as well as to introduce them into the handling of a state-of-the-art simulation tool.
Contents	1. Introduction Operating the computer and handling of the simulation tool MatLab 2. The DFT Introduction, Definition and properties of DFT and FFT 3. The sampling theorem: Sampling errors; sampling rate conversion; bandpass subsampling 4. Filters with limited impulse reponse FIR-Filter: FIR filters; FIR filters in the frequency domain; FIR filters with linear phase; design of of linear phase FIR filters by fourier approximation; FIR multi rate filters 5. Random signals: Properties of time discrete random processes; practical measurements applied to realizations of ergodic time discrete random processes; random number generation; examples of random signals 6. Coding: Introduction to source coding and cryptography 7. Channel Coding: Introduction to channel coding; Block codes; Convolutional codes; Viterbi algorithm 8. Digital modulation modes: ASK, PSK, DPSK, QAM; impulse forming, eye pattern; disturbance by AWGN; dectectors 9. Code Division Multiple Access: Spectrum; Correlation properties; Robustness; RAKE-Receiver 10. Orthogonal Frequency Division Multiplexing: Multi-carrier system with IFFT; OFDM and AWGN; OFDM in multipath scenario; Peak power problem; 11: Software Defined Radio and Simulink: Introduction to time, frequency and phase synchronization methods; Model-based waveform development with Simulink and the Universal Software Radio Peripheral (USRP) The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The participants are provided with a detailed laboratory manual.
Language	German
Examination	Oral (see actual document "Studienplan" and notice of the examination office ETIT).

Formation of grade	The final mark is composed from the engagement during the experiments, solving of preliminary problems, maintenance of the protocol booklet, and the oral examination.
Course form	Practical computer exercises in groups of two students.
General remarks	The professor reserves the right to substitute experiments described in the document by others without prior notification. The number of participants is limited to 14 per semester.

Course name	**Signal Processing in Communications**
Course code	**23534**
Lecturer/ Institute	Dr. Jäkel / INT
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Communications 1, Probability Theory
Objectives	The goal is to relay theoretical fundamentals
Brief description course	The lecture discusses the manifold applications of signal processing principles in communications
Contents	The lecture focuses on the practical use of vectors and matrices in the description of telecommunication systems. Digital transmission is based on the transformation of physical signals into matrices. This may be done by using a sampling operation or by applying a bank of correlators. Simple preliminaries presented within the lecture result in mathematical descriptions which simplify and explain some of the algorithms used in telecommunications. The methods discussed in the first part of the lecture are the basis for multiple algorithms in digital communication. Many methods can be reduced to the same mathematical principle, e.g., detection, multi-user separation and filter optimization. Thus, for a deeper understanding, the basic ideas are more important than a detailed knowledge of individual realizations. In order to demonstrate the elaborated principles, the simplified methods resulting from the mathematical description are applied to up-to-date topics in communications, e.g., problems arising in estimation theory, matched filter whitening, diversity techniques, multiuser detection, MIMO transmission and equalization. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Script is provided. Those topics which are not extensively elaborated in the script are taught according to well-established communication textbooks. Further reading is recommended in the lecture.
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Applied Information Theory**
Course code	**23537**
Associated Exercise	23539
Lecturer/ Institute	Dr. Jäkel / INT
Credit Points	4,5+1,5
Semester hours	3+1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Communications 1, Probability Theory
Objectives	The goal is to relay theoretical fundamentals
Brief description course	The lecture discusses the fundamentals of information theory, especially focussing on their application in communications.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.
Contents	The methods of information theory defined by C. Shannon are very important for the analysis of source coding techniques. In order to provide a sound basis, the lecture starts with defining the tools of information theory. Based on information theory, both fixed and variable length coding of discrete sources are presented, and their advantages and disadvantages are discussed. Afterwards, practical methods of source coding are introduced and their properties are analyzed. Due to the fact that all methods discussed so far operate for discrete sources, information theory of continuous variables and the relations of continuous signals and their digitized versions is another subject in the lecture. Regarding the security of transmitted data, cryptography is an important element of today's communication. The algorithms of cryptology are conducted in the transmitter and map data blocks onto data blocks, thus being a coding operation. Therefore, the lecture also covers the principles of cryptology. Based on simple ciphering mechanisms, fundamental principles and problems of cryptology are discussed, and block ciphering and stream ciphering are introduced. Today's e-commerce is based on secure ad-hoc communication which provides security without prior key exchange. Originating from a short survey of mathematical basics, the principles of public-key-cryptography are described. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Script is provided. Those topics which are not extensively elaborated in the script are taught according to well-established information theory textbooks. Further reading is recommended in the lecture.
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture and tutorial

Course name	**Advanced Radio Communications II**
Course code	**23538**
Associated Exercise	23540
Lecturer/ Institute	Dr. Jäkel / INT
Credit Points	3+1,5
Semester hours	2+1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Signal Processing, Probability Theory, Basic knowledge of communications (e.g., Nachrichtentechnik I)
Objectives	Theoretical fundamentals of digital wireless communications are to be covered.
Brief description course	The lecture complements the topics discussed within the basic course Nachrichtentechnik I. For this purpose, new perspectives are added to already known topics and problems are covered, which were not part of Nachrichtentechnik I.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises. The presentation is assisted by computer simulations.
Contents	The lecture complements the knowledge developed in bachelor courses by improving scientific foundations and implications. Additionally, new topics are introduced which were not part of any other lecture. Preliminaries of probability theory, system theory, and communications are recommended. Band-pass sub-sampling is discussed and its relevance is made clear by the super-heterodyne receiver. Thereafter, numerical realization of Fourier transformation by FFT is recapitulated and complemented. Frequency selective digital filters are an important component of communication systems. Therefore, their design is discussed from scratch and design methods are elaborated. Additionally, the lecture contends an extensive discussion of channel modeling. The objective is to achieve a detailed description of wireless channels such that these models can be used for the simulation of wireless communication systems. Channel models and their parameters are directly related the transmission technique and the corresponding frequency range. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Slides are provided. Further reading is recommended in the lecture.
Language	English
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture and Exercises

Course name	**Job Description of an Engineer in Modern Companies**
Course code	**23541**
Lecturer/ Institute	Prof. Dr.-Ing. Helmut Klausing / INT
Credit Points	3 (block)
Semester hours	2 (block)
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Key Qualification
Prerequisites	None
Objectives	Goal is to gain an understanding of the job description and profile requirements for engineers in an international environment.
Brief description course	The lecture demonstrates how modern companies take advantage of the creativity of their staff by using innovation management to turn ideas into competitive products and benefit from the chances of globalisation.
Contents	Innovative ability is more and more becoming the leading edge for companies operating in international markets. This results in the necessity to change internal processes, performances and products in step with the demands of the market and the competition. For this reason successful enterprises make use of the creativity and entrepreneurship of their employees. The lecture demonstrates how modern companies set up their organisational structures and internal decision making procedures in order to be able to offer competitive products and services in a global market. The profile of career starters and criteria for the professional orientation and personal development within a company structure are analysed and discussed. The roles of employees and managers in reaching objectives are considered. Furthermore, job specifications and required standards for engineers within an international environment will be outlined. Using current examples from the business world, the value creation chain is demonstrated ranging from the first idea to the successful marketing of a product The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Handouts are available before the lecture.
Language	German
Examination	Written
Formation of grade	Grades result from the written examination
Course form	Lecture
General remarks	The presentation consists of a series of consecutives modules. The feature of the lecture is the reference to the practical professional application.

Course name	**2D Signals and Systems**
Course code	**23543**
Lecturer/ Institute	Prof. Tacke / INT
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Elementary signal processing
Objectives	The goal is to lay a theoretical and practical basis, with central application of image processing and analysis
Brief description course	The lectures cover the basics of two dimensional signals, data and systems. General fundamentals are discussed such as transformations, especially the two dimensional Fourier transformation. Central applications are in imaging systems with topics like image formation, preprocessing, textures, segmentation and elementary pattern recognition techniques.
Contents	The first lecture gives an overwiew of the whole subject and the covered material. The first topics are digitisation and Fourier-Transformation of two-dimensional distributions. These are essential basics of the following scientific and technical contents. The next chapter deals with point and neighbourhood operations. Both are used frequently for image processing and are the first step of image analysis. Segmentation is the foundation of automatic image understanding. Segmentation separates data points of objects under consideration and other objects (the background). Different techniques are introduced. The character of segmented data is automatically described by features extracted from them. Their use for classification is described, and techniques for classification are explained. Technical image formation is treated both for optical sensors and for techniques that make use of two-dimensional transformations of sensor material for image formation: tomography and radar with synthetic aperture (SAR). One chapter is devoted to detection and tracking of motion in image sequences, and one to techniques for gaining three-dimensional information of 3D – scenes from image pairs and image sequences. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Written material is distributed during the lectures. The contents are covered by introductory textbooks on image processing and signal analysis.
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**OFDM Based Transmission Techniques**
Course code	**23545**
Lecturer/ Institute	Dr. Schnell / INT
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	None
Objectives Brief description course	The goal is to relay the theoretical fundamentals of multi-carrier communications. The main focus of this lecture is on the theory of multi-carrier communications. The multiplexing technique OFDM (Orthogonal Frequency-Division Multiplexing) is described in detail which is the common basis for multi-carrier systems. In addition, multiple-access techniques which are based on OFDM are presented and discussed.
Contents	This lecture comprises a theoretical treatment of the most important multi-carrier communications techniques. In addition, existing and planned multi-carrier systems and standards are presented and discussed. Requirement for participation in this lecture is basic knowledge in digital communications. The lecture starts with a short revision course on the theoretical basics in digital communications and continues with the treatment of OFDM. The theory behind OFDM is described in great detail and the resulting characteristics are explained and discussed. Besides the basic OFDM principle and the role of the guard interval methods for synchronization, channel estimation, and equalization are considered in detail. Basic concepts for the OFDM system design complete the first part of the lecture. The second part of the lecture is devoted to multi-carrier based multiple-access systems. It is explained, how the standard multiple-access systems TDMA, FDMA, and CDMA can be combined appropriately with OFDM. Especially, the theory of the following multi-carrier multiple-access systems is described in detail: Multi-Carrier Code-Division Multiple-Access (MC-CDMA), Multi-Carrier Direct-Sequence Code-Division Multiple-Access (MC-DS-CDMA), Spread-Spectrum Multi-Carrier Multiple-Access (SS-MC-MA) and Orthogonal Frequency-Division Multiple-Access (OFDMA). In addition, Interleaved Frequency-Division Multiple-Access (IFDMA) is explained and discussed which constitutes a special case of multi-carrier technique, since in contrast to the above mentioned techniques IFDMA allows for a pure time-domain realization. In addition, the relation between IFDMA and OFDM is presented. Multi-carrier multiple-access techniques are currently under discussion for the next generation mobile radio system (“4G”). The third and last part of this lecture deals with standardized wireless OFDM systems. Both broadcast and point-to-point communications standards are considered: DAB (Digital Audio Broadcasting) and DVB-T (Digital Video Broadcasting – Terrestrial) as examples for broadcast standards, and HIPERLAN/2 (HIgh PERformance Local Area Network), the European variant of the IEEE 802.11a standard, as example for a wireless local network standard. In addition, the basic concepts of WiMAX and LTE (Long-Term Evolution of 3G mobile radio) are explained. The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	The material for the lecture is available via e-mail request addressed to the lecturer. (E-mail: Michael.Schnell@DLR.de)
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Error-Control Coding**
Course code	**23546**
Lecturer/ Institute	Prof. Friedrichs / INT
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic skills in communications engineering recommended, background in basic mathematics required
Objectives	Introduction to basic theory and applications.
Brief description course	The focus is on the formal and mathematical fundamentals for the design of error-control systems in digital communication systems and on the Shannon information theory. Practical aspects and implementation issues are addressed in the context of various real-world applications.

Contents

Overview

This lecture presents an introduction to the important theoretical fundamentals, practical aspects and applications of error-control coding in modern digital communication systems. This includes also some basic facts from Shannon information theory.

Coding and information theory is actually based on a rich field of various mathematics disciplines (statistics and stochastic processes, linear algebra and matrix theory, polynomials, finite state machines, Galois fields, etc.), however, the use of theory is kept to the required minimum in order to have also time for covering implementation aspects and important applications.

Some examples of coding performance are highlighted using Matlab / Simulink live demonstrations.

Contents

1) Introduction to Coded Digital Communications (Coding for Reliable Digital Transmission and Storage; Elements of Digital Communication Systems; Discrete Channel Models; Block Coding; Hamming Distance and Minimum Distance; Maximum-Likelihood Decoding; Asymptotic Coding Gains; The Basic Idea of Error-Correcting Codes)

2) Shannon Information Theory (Channel Capacity of Discrete Memoryless Channels; Channel Coding Theorems; Capacity Limits and Coding Gains for the Binary AWGN Channel; C and R_0 for AWGN Channels with High-Level Modulation; Band-Limited AWGN Channels)

3) Linear block codes (Structure of Linear Block Codes; Error Detection and Correction and Their Geometric Representations; Bounds on Minimum Distance; Asymptotic Bounds on Minimum Distance; The Weight Distribution; Error-Detection Performance; Error-Correction Performance)

4) Matrix Description for Linear Block Codes (The Generator Matrix; The Parity-Check Matrix; Hamming Codes and Applications; Simple Modifications to a Linear Code; Simple Decoding Techniques)

5) Cyclic Block Codes (Polynomial Description of Cyclic Codes; The Generator Polynomial; The Parity-Check Polynomial; Systematic Encoders; The Syndrome Polynomial; Burst-Error and Single-Error Detection Coding; Burst-Error and Single-Error Correction Coding)

6) The Arithmetic of Galois Fields and Fourier Transforms (only some basic ideas)

7) Reed-Solomon and Bose-Chaudhuri-Hocquengham Codes (Representation and Performance of RS and BCH Codes; Some Basics of Decoding; Error-and-Erasure Decoding with RS Codes; Modifications to RS Codes)

8) Description and Properties of Convolutional Codes (Linear Encoders and Shift Registers; Polynomial Description; Truncated Convolutional Codes; Punctured Convolutional Codes; Catastrophic Codes and Encoder Inverse; Distance Properties and Optimum Convolutional Codes; The Trellis Diagram; State Diagrams and Weight Enumerators)

9) Maximum-Likelihood Viterbi Decoding and Performance of Convolutional Codes (Maximum-Likelihood-Decoding and the Viterbi Metric; The Viterbi Algorithm; Calculation of Error Probabilities and Performance Results; Concatenated Codes and Requirements on Soft-Decision Output; Comparison of Block and Convolutional Codes)

10) Trellis Coded Modulation (only some basic ideas)
11) Selected Applications (Satellite Communications; Modems for Data Transmission over the Voice-Band Telephone Channel; The GSM Standard for Mobile Radio; Source and Channel Coding for Future Mobile Radio; Broadband Wireless Point-to-Multipoint Access Networks as an example for adaptive coding and burst operation; The Compact Disc)

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Based on the textbook: Bernd Friedrichs: Kanalcodierung - Grundlagen und Anwendungen in modernen Kommunikationssystemen. Berlin: Springer-Verlag 1995. Weitere Infos auf www.berndfriedrichs.de
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Spectrum Management**
Course code	**23547**
Lecturer/ Institute	Dr. Löffler / CEL
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Communications 1, Fundamentals of Microwave Engineering
Objectives	The intention is to convey an overview
Brief description course	The lecture discusses the technical, political, administrative and economical aspects of spectrum management.

Contents

Radio frequencies are a natural resource. Luckily they are occupied but not consumed by use. Nevertheless, the various parts of the spectrum are not equally useful. Some parts are good for some purposes, other parts are technically preferable for other purposes. Hence there are technical reasons for selecting one or the other frequency for a given application. On the other hand the Titanic disaster around a hundred years ago showed to the public the profit of standardizing frequency usage what fortunately started around six years before. At an international radiotelegraph convention the SOS distress signal was adopted.

Today allocating frequencies for certain usages still has an eye on the distress and safety applications but is has become much more. Today it is a fundamental basis for the interoperability of devices, networks and services everywhere. It is also the essential basis for all communication companies to sell their products all around the world. This allocation of frequencies is the core of spectrum management.

The lecture starts with basic technical aspects. Wave propagation within different frequency ranges is discussed and popular models are presented. Antennas are introduced; their properties at different frequency ranges and for different applications are highlighted. The signals transmitted and received as well as filters are presented together with basic calculation methods. Link budgets for the useful and the interfering signal path are examined. Interference accumulation algorithms as well as decision thresholds like C/N, C/I, C/(I+N) are discussed.

In a second part the lecture presents fundamental political and administrative aspects. Organisations and groups active in the spectrum management area are presented. The concept of services as a basis for the allocation of spectrum is introduced. Different methods for the subdivision of the electromagnetic frequency spectrum are shown.

The third area revisits topics discussed in the first and second part and shows their utilization within the frequency planning and assignment processes. The two basic ideas "first come, first serve" and the planning approach are compared. Financial aspects (fees, auction processes) for the steering of frequency use are presented. Last but not least - as part of enforcement procedures - monitoring techniques and location finding methods are described.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Paper copies of the presentation (slides) are provided during the lecture. All slides are in English. Further references as well as internet-links are announced during the lecture.
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture

Course name	**Multirate Systems**
Course code	23548
Associated Exercise	23549
Lecturer/ Institute	Prof. Dr.-Ing. H.G. Göckler (Ruhr-Universität Bochum), INT
Credit Points	3+1,5
Semester hours	2+1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basics of Digital Signal Processing
Objectives	The goal is to relay theoretical and practical fundamentals
Brief description course	Presentation of fundamental methods to represent, analyse, simulate, and synthesise digital multirate systems in conjunction with associated filter banks as well as signal flow graphs of the underlying algorithms.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.
Contents	Tasks and goals of sample rate conversion. Fundamentals of sample rate conversion: Discrete sampling, polyphase and aliasing component representations. Sample rate reduction and increase, synchronous decimation and interpolation by an integer (L ,M) and a rational (L /M) conversion factor, asynchronous, time-varying sample rate conversion. Transposition of multirate systems: Complementary and inverse system, transposition invariant properties. Basics on filter design for multirate systems: appropriate specification, survey of design approaches and their suitability. Efficient filter structures for sample rate conversion: FIR filters, polyphase and Farrow structures. Efficient algorithms for sample conversion. M-channel filter banks: Analysis and synthesis bank (matrix representation), frequency (de)multiplexer, subband coder and transmultiplexer filter bank. Aliasing-free and perfectly reconstructing filter banks, paraunitarity, spectral factorisation. Efficient filter bank implementations: Uniform complex-modulated filter bank, DFT-polyphase filter bank, tree-structured filter banks. Applications (CATV system, satellite communications); Challenging exercises with detailed standard solutions supplemented with share-ware MATLAB routines in Internet The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Textbook „Multiratensysteme“ is provided (15 copies) by the university library. It represents the basis of lecture and exercises.
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination

Course form	Lecture and practical design course

Course name	**Systems and Software Engineering**
Course code	**23605**
Associated Exercise	23607
Lecturer/ Institute	Prof. Dr.-Ing. Müller-Glaser / ITIV
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Master
Elective course	Master
Prerequisites	Participation in the lectures Digital System Design (23615) and Information Technology (23622) is advised

Objectives

By the end of this course students should be able to recall life cycle models for the design, implementation, integration, test, operation and maintenance of embedded electronic systems (V-model, Hunger-model). They should understand different implementation alternatives and road maps for microelectronic circuits and systems. They should understand basic concepts, views and methods for describing software, especially the graphical descriptions of the Unified Modeling Language (UML and SysML) They should be able to apply systems engineering concepts and computer aided tools to analyze, interpret and predict the behavior and performance of a programmable electronic system or micro system. They should be able to evaluate criteria for system optimization with respect to performance, energy consumption, layout area and costs for the design of embedded electronic systems comprising hardware and software.

Brief description course

Major topics are methodologies and computer aided engineering tools for the design of complex electric, electronic and programmable electronic systems with software fragments and hardware fragments. The competences of the course comprise comprehensive knowledge and goal-oriented usage of state of the art modeling techniques, development processes, description techniques as well as specification languages.

Brief description exercises

Complementing the lecture the exercise session expresses practical problems concerning the lecture topics and discusses case studies. Detailed solutions and use cases are presented and discussed during lecture hall exercises. The tutorial relates the theoretical content of the lecture to its concrete usage.

Contents

Lecture

The lecture Systems and Software Engineering is directed to all students, who themselves want to be challenged with the design of complex electronic systems with hardware and software components. To prepare for working in international teams the lecture is presented in English language. It will introduce to students the tools, which allow for a structured solution of complex problems. The lecture specially dwells on development processes, hardware design, software design, reliability as well as various aspects of modeling.

The lecture initially differentiates the terms system, systems engineering and software engineering. Life cycle models and methods for mathematical modeling of embedded electronic systems as well as lifecycle models (Waterfall model, V-Model and Hunger Model) are introduced. The focuses of the lecture are the early phases of system development, starting with definitions of requirements as well as the creation of project requirement documents and functional specifications. Aspects of requirements documentation methods and description techniques as well as specification languages and formalisms are brought near.

Concrete topics in the area of hardware design are state charts, realization alternatives for electronic computation systems, aspects of concurrency and parallelization, pipelining, scheduling, real time systems and the appropriate operating systems.

The domain reliability broaches the issue of safety and security and operability of complex electronical systems covering their complete lifetime. Mathematical modeling methods as well as risk analysis and simplified presentations like reliability block diagrams are discussed.

Besides the various diagrams and modeling perspectives of UML (Use Case diagram, class diagram, object diagram, communication diagram, sequence diagram, package diagram, etc.) the area of software design covers dataflow diagram, Petri nets as well as various languages like EBNF.

Testing and maintenance form another essential aspect of the system development. Approaches and procedures like black box testing and white box testing are presented and form a basic understanding for the importance of testing, verification and validation as well as quality assurance all over the development period.

Exercise
Exercises concerning the lecture as well as their appropriate solutions are handed out and discussed in the lecture hall exercise session. Transferring the lecture's theoretical content to examples with practical orientation clarify the usage and necessity of techniques for modeling and representation techniques.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org
Language	English
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks, exercises, and tutorials. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**System Analysis and Design**
Course code	**23606**
Lecturer/ Institute	Prof. Müller-Glaser / ITIV
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic knowledge of embedded systems is beneficial
Objectives	Understanding methodologies for analysis and design of heterogeneous electronic systems with hard real time constraints. Understanding design for X techniques. Understanding of CMOS technology.
Brief description course	Focuses of the lecture are processes and methods for the analysis and design of embedded electronic systems. Further focuses are the various alternative technologies available for realisation of such systems.
Contents	Lecture This course provides methods of analysis and design of embedded electronic systems. First the lecture repeats important basics in the field of embedded electronic systems. The concept of embedded electronic system is repeated with the help of the example of ECUs in vehicles. Thereafter, the requirements for such systems are shown by the topics real-time requirements and reliability. It is shown what possibilities operating systems provide for the realization of distributed embedded systems. It identifies various technologies and criteria for their selection for the individual control units as well as the communications architecture of the entire system are available. The next chapter addresses the systems engineering process. First, the necessity of processes in system development is outlined. Thereafter, the process of the V-model and the process according to Hunger are presented. The following chapters are devoted to the various aspects of the Design for X concept. Starting with the Design for Performance in which students gain skills for the determination of performance and energy consumption of CMOS circuits. This is supported by knowledge about packaging and interconnection. The next chapter deals with the topics quality, safety and reliability. The students are taught methods are like Fault Tree Analysis, Failure Mode and Effect Analysis and more which allow the estimation and reduction of risk. Design for Testability covers techniques and methods for reliable and efficient detection of faults in electronic systems. This covers both manufacturing errors and defects due to aging. The finale is the topic of Design for Manability dealing with the ergonomics of electronic systems. It takes different aspects of the human body and perception into account. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.estudium.org
Language	German
Examination	Written (winter term) / Oral (summer term) (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination

Course form	Lecture
General remarks	Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Hardware Modeling and Simulation**
Course code	**23608**
Associated Exercise	23610
Lecturer/ Institute	Prof. Müller-Glaser / ITIV
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Lecture „Systems and Software Engineering“ (23605)

Objectives

By the end of this course students understand hardware description languages for different levels of abstraction (circuit, logic, algorithmic, system level) and different views (behavioural, structural, geometrical). Students understand the function of simulation kernels for logic simulators, circuit simulators and system simulators with multi-level, mixed mode modelling. Students understand sequential and concurrent statements of the hardware description language VHDL, they can apply VHDL to write models for novel designs of digital circuits. In using simulation they can interpret and predict the behaviour of a design with respect to specified functions, given timing constraints and tolerances due to variation of loads, power supply voltage, ambient temperature and manufacturing tolerances. Thus they can analyze, plan and design novel digital systems, they can optimize these circuits and systems with respect to performance, energy consumption, layout area and costs. Another aim of this lecture is to provide the

Brief description course

Through the support of CAE tools, which spread out quickly in the recent years, the design process of electronic systems could be accelerated significantly. The basic design of electronic systems using CAE tools and hardware description languages is being learned in this lecture. Knowledge about methods for checking the correctness of designs will be received as well as requirements for industrial design automation systems. Special attention will be given to the design tools LOG/iC, Statemate, and MatrixX.

Brief description exercises

Supporting the lecture, exercise sheets are being provided. Their solution is presented in detail and discussed during lecture hall exercises.

Contents

Lecture

At the beginning of the lecture the design process for integrated circuits and embedded systems is introduced. Solution strategies are given to cope with the challenges of designing complex systems. The different approaches are presented and illustrated by examples. Finally, the use of hardware description languages is motivated.

In the second part of the lecture the hardware description language VHDL presented. First, the principle structure is explained and examples for the application are given. The concepts and syntax are explained on the basis of examples. With the help of the Y-diagram the different levels of abstraction in VHDL are explained as well as the modeling of behavioral and structural descriptions. Then the representation of sequential and parallel statements and the different delay models are described in detail. Furthermore, the methodology for testing VHDL models and the use of context commands is explained. Finally, the nine-value logic system as well as the design of final state machines is explained by example. explain

The third part of the lecture deals with verification, validation and simulation. Following the system-level simulation, the logic simulation is introduced. Therefore the modeling of logical and timing behavior is clarified. The simulation process is explained on basis of the different VHDL timing models. Finally, fault-simulation with the presentation of error classes as well as the appropriate test methods are introduced. The area of circuit simulation deals with the modeling of analog circuits as well as the simulation steps. The modeling of mixed-signal systems is supported by the introduction of the VHDL-AMS extension. In the area of the physical level simulation, semiconductor process simulation methods and the finite element method are explained. The areas of rule checking and formal verification deal with the plausibility criteria and the compliance of implementation and specification.

In the last part of the lecture, the modeling language Verilog is being compared to VHDL and an overview of system modeling in System C is given.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org. Literature references are given in lecture slides.
Language	English
Examination	During semester written, otherwise oral examination (see actual document “Studienplan” and notice of the examination office at ETIT).
Formation of grade	Grades result from the written respectivley the oral examination
Course form	Lecture, Exercises
General remarks	The course comprises of the blocks lecture and exercises. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Software Engineering**
Course code	**23611**
Lecturer/ Institute	Dr. Clemens Reichmann / ITIV
Credit Points	3
Semester hours	2
Term	Winter Term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Knowledge from Systems and Software Engineering (course 23605)
Objectives	Consolidation and enhancement of knowledge and comprehension about methods and tool in software engineering.
Brief description course	Based on the course Systems and Software Engineering (SSE) software-specific knowledge are deepened. For competence evolvement of students a deepened comprehension of necessity and application of approaches, aids and tools from all areas of software development is aspired.

Contents

The lecture Software Engineering addresses all students wanting to deal with design and development of complex software systems. It is aimed to provide techniques, methods, and tools that allow for a well structured and targeted solution of even complex problems. Addressed is the complete lifecycle of software products from requirements to maintenance and further development.

At first the lecture covers basics and background like terms, processes, general methods and process models for software design. Hereby special emphasis is laid on comprehension of emergence and necessity of the engineering approach in software development. This is based on knowledge provided in the lecture Systems and Software Engineering (SSE), especially knowledge about the unified modeling language UML.

As a starting point of the considered development process, collection and management of requirements is covered (Requirements Engineering, Requirements Management). Concretely introduced are methods and tools like SysML and EEKT.

To empower students to execute complex projects on their own, a next focus is on project management, considering especially software development. The necessity of accurate planning and targeted execution is depicted and methods for organization, surveillance and structuring are given.

Looking at the topic of software design different approaches like modular design and object-oriented design are introduced, compared and rated according to their benefits and drawbacks. Students shall be able to select appropriate approaches depending on the project.

As an important aid for design and realisation of software systems design pattern are presented and discussed that provide possible solution structures based on longtime worldwide experience. Students shall so be provided a toolbox of adaptable solution ideas. Subsequently implementation and according tools are concretely discussed.

As an additional crucial point in designing systems a focus is laid on refactoring and programming quality. Here criteria are given to identify and improve potential problems, so-called bad code smells.

An essential area in software engineering and also in the lecture is reuse of software. The lecture details alternatives and potentials for software reuse on various levels (e.g. libraries, frameworks, modules, pattern, …).

Finally meta modelling and model based development is a topic with UML as an example. Discussed are among other things different meta models, MDA and XMI. Also model transformations and different techniques for model-to-model transformations are given.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Material for the lecture is provided online at www.estudium.org. To all chapters enhanced literature is given in the material.
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**System-On-Chip Laboratory**
Course code	**23612**
Lecturer/ Institute	Prof. Becker – ITIV / Prof. Siegel - IMS
Credit Points	6
Semester hours	4
Term	Winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Knowledge in the design of analog and digital highly integrated circuits, e.g. from the following lectures: DDS (23683), DAS (23664), HMS (23608), HSC (23620), HSO (23619)
Objectives	This laboratory allows gaining practical experience in applying Hardware/Software Co-Design techniques to a RISC based System-on-Chip architecture for OGG-Vorbis audio decoding. Therefore, analogue as well as digital hardware modules have to be developed and added to the SoC design. Besides, also the source code of the audio decoder has to be adapted in order to make use of the developed hardware components. Afterwards the design has to be synthesized for different technologies (FPGA, standard cells, and analogue layout). In this context knowledge of handling state of the art tools for FPGA, standard cell and analogue circuit design is imparted. Each major step in the design flow is accomplished by applying verification methods that ensure the correct behavior of the system.
Brief description course	In this laboratory a mixed signal SoC design will be realized that will allow the decoding of OGG-Vorbis audio streams. The design of the SoC requires the development of analogue as well as digital SoC components, the verification of the system and finally the implementation based on different technologies such as FPGAs ors standard cells.
Contents	This laboratory offers the possibility to extend the theoretical knowledge of analogue and digital circuit design by a practical example. Therefore, a mixed signal System-on-Chip will be implemented that realizes an audio player for OGG-Vorbis audio decoding. The laboratory is organized as a block course and covers three major topics – HW/SW Co-Design & FPGA prototyping, standard cell and analogue circuit design. The first part of the laboratory is used to obtain a detailed understanding of the system. Initially the embedded system is made up of the freely available LEON processor as well as modules that are required for FPGA prototyping. As it finally should realize a sophisticated OGG-Vorbis decoder, a dedicated hardware module has to be implemented to accelerate the IMDCT computation which is the most demanding algorithm of the audio decoding application. This model has not only to be integrated in to the system in a following step; also the decoding application has to be modified in order to access the IMDCT hardware accelerator instead of using software routines. In this way the interrelation between the individual components of the SoC can be studied by applying HW/SW-Co-Design principles. This context also enables to show debugging strategies and validation methods for embedded systems with increased complexity. Once the system extension has been finalized, a simulation will be performed to ensure proper functionality before a FPGA prototyping

The focus of the second part of the laboratory lies on a standard cell implementation of the embedded system. In order to be able to perform a synthesis for the Austria Microsystems (AMS) 350nm standard cell process later on, a technology porting of the technology dependent HDL parts has to be done. Therefore, a concept has to be developed that shows how the register file of the LEON processor can be build up by instantiating suited AMS RAMs. Once this step has been finished and a VHDL implementation has been generated, the correct functionality of the design has to be shown by simulating the system using Mentor ModelSim. After a successful, correct simulation, the synthesis process is the next step that has to be run through. In order to accomplish this task, the synthesis script for the Synopsys Design Compiler has to be extended to report relevant design parameter such as the area of the design as well as the length and track of the critical path. Upon availability of the generated netlist, also hereafter a simulation has to be made in order to verify the functionality. Finally,

The third part of the lab is focused on analog design. The task is, to design a sigma delta digital-to-analog converter and an audio amplifier. To learn the basics in analog design, first a Cadence® tutorial has to be done. At the next step a guided design of a folded cascode operational amplifier has to be performed under conditions like gain, bandwidth, stability and slew rate. The next step is applying this amplifier in a low pass filter as the analog end of the d-to-a converter. To solve the specifications of the audio amplifier, a redesign of the output stage of the operational amplifier is needed. Finally the modelling and optimisation of the digital parts of the sigma delta converter has to be done, using the Matlab/ Simulink software. The result is saved as VHD code for further processing using tools from the 2nd part of the lab.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org
Language	German and/or English – upon the choice of the students
Examination	Oral: 3 x 20 minutes, concluding the weekly worked-on topic. Written: protocol of the laboratory (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination and the written laboratory protocol
Course form	Laboratory
General remarks	The laboratory will take place as a three week block course. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Seminar: System-on-Chip (SoC) – Architectures and Applications**
Course code	**23614**
Lecturer/ Institute	Prof. Becker / ITIV
Credit Points	3
Semester hours	2
Term	Winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	None
Objectives	The goal of this seminar is to convey the ability to independently familiarize with a given technical topic, identify all relevant aspects and sum up the results in a presentation.
Brief description course	In the seminar „System-on-Chip (SoC) – Architectures and Applications“, the students carry out a literature und Internet research on a given topic under the supervision of the research assistants, and prepare a short text (approximately a 30-page composition) as well as a 30-minute presentation to introduce the topic for the fellow students.
Contents	Due to the enormous technology developments of the last years it is now possible to integrate complete hardware/software systems on a single chip – a so-called System-on-Chip. A typical architecture of such systems consists of microcontroller-, DSP-, ASIC- and reconfigurable hardware components. The application specific parameters for the SoC design have to be identified according to flexibility (risk minimisation), chip area (costs), energy consumption (mobility) and data throughput (performance). The Seminar offers students the possibility to work on industry related projects with the emphasis on SoC integration of communication technology applications such as broadband mobile communication systems (UMTS, Software Radio) and Wireless LAN (Bluetooth, Hiperlan). The effects of network properties on the data transfer and security layers will be a major concern. To satisfy the demands of such dynamic protocols regarding the needed high data rates (e.g. for mobile multimedia applications) adapted development processes, adaptive hardware/software architectures and efficient digital communication algorithms have to be developed. Topics of seminar projects will be in the focused on interdisciplinary integration of system design, CAD and microelectronics. The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German or English
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the composition and the presentation.
Course form	Seminar
General remarks	Current information can be found on the ITIV webpage (www.itiv.kit.edu).

Course name	**Digital System Design**
Course code	**23615**
Associated Exercise	23617
Lecturer/ Institute	Prof. Becker / ITIV
Credit Points	4,5 + 3
Semester hours	3 + 2
Term	Winter term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	none
Objectives	The goal is to relay theoretical fundamentals.
Brief description course	Digital design fundamental lecture. Focus of the lecture are formal, methodical and mathematic fundamentals for the design of digital systems. Based on these, technical implementation of digital systems is elaborated, especially the design of standard digital building blocks and more complex systems based on these.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises. Subsequently more dedicated assignments in form of tutorial sessions, in form of small study groups, are offered to deepen the understanding of the curriculum's as well as the exercises contents.
Contents	Lecture

This lecture presents an introduction to the important theoretical fundamentals of digital system design, which is scheduled for the students in the first semester of Electrical Engineering. Since the lecture can not be based on student's knowledge of circuit technology, it focuses on abstract models for behaviours and structures. In addition the lecture will also relay the fundamentals, which are needed in other lectures.

At first the lecture delves into important conceptual information and shows that digital system design represents a special technical solution for the treatment of information. After this the concept of a system will be introduced and illustrated that complex systems require a hierarchical partitioning in order to be able to understand and design them. Based on this it can be concluded then that system design can be understood as a repeated transformation from descriptions of behaviour to descriptions of structure.

The terms message and signal are subject matter of a further chapter. Starting from time and amplitude continuous signals, simple time and value discrete binary signal representations will be introduced, as well as more complex signal forms derived from binary signals.

The representation of information by signals presupposes or implies an "agreement of allocation" between distinguishable elements of information representation and signal representation, the so-called codes. Therefore the lecture delivers the fundamental concepts of codes & coding and describes a few important classes & types of codes, which serve some of the following uses: analogue/digital conversion for interfaces, error detection & error correction for numerical purposes, and optimal representation of information and/or signals. Code conversion and related topics finalize the consideration of this topic.

Formal and mathematical fundamentals will be treated in an extensive chapter. To begin the subject matter of the lecture is comprised of sets and quantities, the operations on these quantities, as well as the relations between set elements. Afterwards several fundamentals of graph theory are introduced. It will be shown that logic algebra can serve as a basis for special Boolean algebra. Building upon the associated rules the concept of switching functions, their graphical representation and classification, the standard theories, and important basis systems for the representation of Boolean expressions will be derived and considered. Expansion theory, the computation with allocation blocks and terms, as well as measures for minimization are further topics of this chapter.

Having the formal basics available, applicable technical components and structures will be developed on the basis of binary switches, which allow for a direct conversion of formal relationships into solutions. Gates, circuit networks, synchronized sequential circuits, as well as specially derived functional units such as counters, registers, and digital memories lead to complex structures. The "All-purpose Computer" from J. von Neumann will be particularly dealt with.

Exercises

To accompany the lecture material, assignments and the corresponding solutions will be given out and discussed during lecture hall exercises. Furthermore tutorials in small study groups will be held to deepen the understanding of the curriculum and methods taught. Furthermore computer exercises are offered in which digital circuits and their pattern of behaviour will be modelled and simulated with the help of the program LogicWorks.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org Literature: Hans Martin Lipp, Jürgen Becker; Grundlagen der Digitaltechnik; 6., überarbeitete Auflage 2008.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture, Exercises, and Tutorials
General remarks	The course comprises of the interleaved lecture blocks, exercises, and tutorials. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Communication Systems and Protocols**
Course code	**23616**
Associated Exercise	23618
Lecturer/ Institute	Dr. Hübner / ITIV
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Master
Elective course	Master
Prerequisites	This lecture is based on the lecture „Digital System Design“ (Lecture no. 23615).
Objectives	The goal of this lecture is to introduce basic concepts of these methods of transmission and to work out common aspects. Some typical und popular solutions are exemplarily treated in more detail.
Brief description course	The lecture presents physical and technical fundamentals for the design and realisation of communication systems. The practical application of this principles is shown on several examples of actual communication systems.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises. Subsequently more dedicated assignments in form of tutorial sessions, in form of small study groups, are offered to deepen the understanding of the curriculum's as well as the exercises contents.
Contents	This lecture for students of electrical engineering and information technology gives an insight into theory and praxis of data exchange in and between computers as well as dedicated communication systems. Different levels of data communication are explained whereby high integrated connections of different components on a microchip via internal system busses as well as wide area networks are covered. Beside the important criterion of speed, respectively the transmission performances of a communication system additional security aspects or costs when designing such a system are considered. Actual implementations are described, among others e.g. serial and parallel interfaces as well as the bus systems PCI, SCSI, FireWire, USB, IEC and CAN. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.estudium.org Literature: Bernd Schürmann; Grundlagen der Rechnerkommunikation; 1. Auflage 2004. Friedrich Wittgruber; Digitale Schnittstellen und Bussysteme, 2002
Language	German
Examination	Written (see actual document "Studienplan" and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture, Exercises and Tutorials
General remarks	The course comprises of the interleaved lecture blocks, exercises, and tutorials. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Hardware-Synthesis-Optimization**
Course code	**23619**
Associated Exercise	23621
Lecturer/ Institute	Prof. Becker / ITIV
Credit Points	4,5 + 1,5
Semester hours	3 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	The students shall be able to demonstrate the capabilities for the optimized design of electronic systems.
Brief description course	Focus of the lecture Hardware-Synthesis-Optimization is on the transfer of formal and methodological basics for design of electronic systems. The selection of the algorithms discussed in the lecture is driven by their practical application and their importance for the industry.
Brief description exercises	The accompanying exercises intend to consolidate the knowledge from the lectures. Selected topics will be repeated and by working on theoretical and practical examples the students will learn to apply the methods in modern system design.

Contents

This lecture presents fundamental and advanced algorithmic methods which are used at the automated synthesis of microelectronic circuits inside modern CAD-tools. Besides theoretical discussions the presented methods will be elaborated by the means of numerous examples and a relationship to practical applications will be established. In this connection the spectrum of system and circuit realization starting from the behavioral description of an hardware description language up to the synthesis and optimization of a gate netlist and the generation of the of physical layouts of today's standard cell technology are expatiated. The presented methods are organized in high-level synthesis, register transfer synthesis, logic synthesis and the physical design as well.

The following themes are treated:

· Design process using computer-aided design
· Relevant graph algorithms and complexity
· Various design methods
· for gate arrays, standard cells, macro cells, reconfigurable hardware

· High-level-synthesis
· Scheduling methods, algorithms for allocation and binding
· Register-transfer-synthesis
· Optimization of Controllers, Retiming of datapathes
· Logic-synthesis
· Two-stage and multi-stage logic optimization
· Technology-mapping of an optimized gate netlist
· Physical design methods
· Various algorithms for partitioning, simulated annealing, genetical optimization

· Floorplanning-, routing- and placement methods
· Global and detailed wiring mechanisms
· Rapid-Prototyping
· Emulation/simulation, technology and ascertained prototyping-systems,

- Application examples

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teaching platform (www.estudium.org).

Course name	**Hardware/Software Codesign**
Course code	**23620**
Associated Exercise	23623
Lecturer/ Institute	Dr. Hübner / ITIV
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	None
Objectives	The lecture intends to relay the knowledge about fundamentals and first principles of HW/SW Codesign. The attendance at the lecture affords the comprehension and classification of target architectures, estimation methods of design quality in early phases of system design as well as partitioning strategies of HW/SW based systems.
Brief description course	The lecture presents theoretical fundamentals for the concurrent and interlocked design of a system's hardware and software components. The practical application of these principles is shown on several examples of actual hardware and software components.
Brief description exercises	The accompanying exercises intend to consolidate the knowledge from the lectures. Selected topics will be repeated and, by working on theoretical and practical examples, the students will learn to apply the methods in modern system design.
Contents	Hardware/Software Co-design is the denomination of the concurrent and interlocked design of a system's hardware and software components. The most modern embedded systems (for example mobile phones, automotive and industrial controller devices, game consoles, home cinema systems, network routers) are composed of cooperating hardware and software components. Enabled by the rapid progress in microelectronics, embedded systems are becoming increasingly more complex with manifold application specific criteria. The deployment of computer aided design tools is not only necessary for handling the increasing complexity, but also for reducing the design costs and time-to-market. The lecture Hardware/Software Codesign discusses the needed criteria & methods and possible hardware/software target architectures on following topics: Target architectures of HW/SW-systems DSP, microcontrollers, ASIPs, FPGAs, ASIC, System-on-Chip Processor design: Pipelining, superscalar, cache, VLIW Estimation of design quality Hardware- and software-performance Methods for hardware/software partitioning Iterative and constructive heuristics Interface and communications synthesis The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.estudium.org Literature: J. Teich, C. Haubelt: „Digitale Hardware/Software-Systeme-Synthese und Optimierung“, Springer-Verlag, 2007 (2. Auflage); D.D. Gajski, F. Vahid, S. Narayan, J. Gong: „Specification and Design of Embedded Systems“, Prentice Hall, 1994
Language	German

Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture and Exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teaching platform (www.estudium.org).

Course name	**Information Technology**
Course code	**23622**
Associated Exercise	23624
Lecturer/ Institute	Prof. Müller-Glaser / ITIV
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	none
Objectives	At the end of the lecture, the students should be able to describe different computer architectures, their structure and functions. Furthermore, the students should understand programming paradigms and compare them. In this context appropriate data structures should be selected. Besides, they can distinguish and evaluate different algorithms based on specific quality features in order determine the appropriate one when conceiving their own programs. At the end of the exercise, students can solve a given algorithmic problem, describing it in different representation forms and implementing it in a structured, executable and efficient C++ program. For this purpose, the main features of C++ programming language should be understood and applied. Another objective is the evaluation of algorithms and programs with respect to certain quality criteria.
Brief description course	Basic course information technology. Main topics of the course are computer architectures, programming languages, data structures and algorithms. Based on that, the design, structure and properties in the process of software design, algorithms and testing are discussed.
Brief description exercises	Accompanying the lecture the exercise procures the fundamentals of the programming language C++ by providing exercises to C++ and the lecture material, as well as showing the solutions in detail. The exercises focus on the design, development and analysis of programs, as well as the implementation of algorithms.
Contents	Lecture

The course provides an introduction to major theoretical fundamentals of information technology. This course is specific to the students of the 2nd semester of Electrical Engineering and Information Technology. Since the students have not yet acquired basic knowledge in computer science, the fundamentals of computer architecture, software development, data structures and algorithms need to be in the main focus. In addition the lecture will also communicate basics, which are needed in other lectures.

In the beginning, the lecture describes the basic terms and shows the areas of information technology to solve complicated problems. Then, basic computer architectures and their relation to the design and execution of programs are discussed. On this basis, the construction and use of programming languages are presented, as well as the basic programming paradigms.

The software development process starting from the analysis of problems concerning the design and implementation up to testing and quality evaluation are shown. In this context, appropriate tools, such as integrated development environments, and the process from source code to an autonomously running program is discussed.

For the description of programs, different representation forms are compared. Furthermore, the principles of object orientated programming are shown. In the next step, the various data structures and their characteristics are presented.

Based on the principles of software development and data structures, different algorithms - their construction and application - are explained. In this context the focus is on the basic algorithms for searching, sorting and optimization. Also their runtime, efficiency and applicability are analyzed. Even more complex and optimized algorithms are addressed and their use in solving current technical problems is shown.

Exercises

In the beginning of the exercise, an introduction to the programming language C++ is presented. This will be done step by step using theory, practical examples and exercises.

First the layout of a C++ program and the fundamentals about variables and operators are introduced. Based on these, pointers, references and arrays are discussed. Subsequently, handling and structuring of major problems, based on the principle of "divide and conquer", is shown. Furthermore, header files, the area of validity and dynamic memory allocation are explained.

The next block deals with advanced data structures and object oriented programming, which has been discussed in the lecture. For reading, processing and storing information, file processing and strings are introduced.

As part of the exercise in different contexts, algorithms are discussed and implemented in C++ source code. Also the efficiency, runtime and behavior of programs and algorithms are analyzed and visualized. Besides, testing following the quality criteria shown in the lecture is part of the exercise.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org; Literature: Kirch-Prinz, U.; Prinz, P.: C++ lernen und professionell anwenden; 4. Auflage 2007; Cormen T. H., Leiserson C. E., Rivest R. L., and Stein C.: Introduction to Algorithms, Second Edition. 2001.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT). Prerequisite: passed lab information technology (23626)
Formation of grade	Grades result from the written examination
Course form	Lecture, exercises and lab
General remarks	The course comprises the interleaved blocks: lecture, exercises and lab. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium teaching platform (www.estudium.org).

Course name	**Microsystems Technology**
Course code	**23625**
Lecturer/ Institute	Prof. Stork / ITIV
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	None
Objectives	The goal of the lecture is to impart a basic knowledge on concepts and procedures out of the wide area of microtechnology and system engineering. In particular the ability to discuss technical subjects with experts of the different technical disciplines shall be acquainted.
Brief description course	Procedures and methodologies out of the area of micro structure technology as microlithography, edging technologies and ultra precise cutting machines are presented and the application of these technologies in the area of micromechanics and microoptics are discussed.
Contents	In the begnning history and concept of microsystems technology will be discussed in the context of applications in automotive, production and medical engineering. Then the major technologies in micro structuring, as lithography, thin film techniques, edging procedures and ultra precise cutting methods are presented. Applications of these technologies especially in the fabrication of micro machining and micro optic components are described. For understanding different classes of microoptic elements an introduction in optics, diffraction and fiber optics technologies will be given. Various classes of microoptical components will be explained. In addition, both the concepts of refractive & diffractive optical components and active & passive waveguides belong to integrated optical systems and fibers. Micromechanical manufacturing processes with silicon and plastic using the LIGA procedure will be demonstrated by means of examples from automotive and medical applications. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Slides and lecture notes are available online on www.estudium.org Literature: Menz, W., Mohr, J., Paul, O.: „Mikrosystemtechnik für Inge-nieure“, Wiley-VCH, 3. Auflage, 2005, Mescheder, U.: „Mikrosystemtechnik“, B.G. Teubner, Stuttgart, 2000, Gerlach, G. und Dötzel, W.: „Grundlagen der Mikrosystemtechnik“, Hanser, München, 1997, Hecht, E.: „Optics“. Addison-Wesley, San Francisco, 2002, Sinzinger, S. und Jahns, J.: „Microoptics“ Wiley-VCH, Weinheim, 1999, Büttgenbach, S.: „Mikromechanik“ Teubner, Stuttgart, 1994, Fatikow, S. und Rembold, U.: “Microsystem Technology and Microrobotics”, Springer, Berlin, 1997, Gardner, J.W. und Varadan, V.K. and Osama O,A.: “Microsensors, MEMS, and Smart Devices”, Wiley-VCH, Weinheim, 2001.
Language	German
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the ITIV webpage (www.itiv.kit.edu).

Course name	**Lab Information Technology**
Course code	**23626**
Lecturer/ Institute	Prof. Müller-Glaser / ITIV
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	none
Objectives	At the end of the lab, the students should be able to decompose complex problems, presented in a natural language (specification), in simple and concise modules. They consequently can use appropriate algorithms and data structures in order to solve the problem. The implementation of a structured and executable source code should take into consideration predefined quality criteria (amongst others coding guidelines). Besides, the students should practice the writing of complex C++ source code and the use of an integrated development environment. This includes the verification of source code by means of test programs.
Brief description course	The lab helps the students to acquire advanced programming skills using the programming language C++. In fact the students are supposed to independently solve a large software problem in form of a project. Therefore they can make use of the acquired basics in the related lecture and exercise and apply them to specific problems.
Contents	The lab aims at applying the theoretical content taught in the lecture and exercise to a concrete problem. Therefore algorithms have to be implemented and tested in the programming language C++. These are embedded in a project based assignment dealing with the issue of time analysis of synchronous circuits. A program framework is provided. The lab is conducted in small teams of four students. The team work is done under the supervision of tutors, who offer their support with respect to technical and project management related questions. Basically the lab takes place in the second half of the semester and is divided into five phases, which last seven weeks. In the first week the students get a specification document, which they use to identify and understand the different tasks. In the next phase, the students should thoroughly plan their project and visualize the conceived modules by means of diagrams within one week. In the next step, which corresponds to the implementation phase, the students should realize their planning by implementing all the required modules and functions in C++ source code. To accomplish this part, they have three weeks time and they additionally need to take into consideration the rules of the given coding guidelines. In the sixth week, an overall test should be carried out in addition to the implemented module tests. In the last week, the documentation of the whole project has to be completed. Each group should provide a documentation of the project according to given guidelines (planning, software and testing). The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org; Literature: Kirch-Prinz, U.; Prinz, P.: C++ lernen und professionell anwenden; 4. Auflage 2007; Cormen T. H., Leiserson C. E., Rivest R. L., and Stein C.: Introduction to Algorithms, Second Edition. 2001.
Language	German
Examination	Written - Delivery of the developed source code and the related documentation (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Certificate
Course form	Lab at PC; part of the course information technology (23622)
General remarks	Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium teaching platform (www.estudium.org).

Course name	**Seminar: Design of Electronic Systems and Microsystems**
Course code	**23627**
Lecturer/ Institute	Prof. Stork / ITIV
Credit Points	3
Semester hours	2
Term	Winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	None
Objectives	The goal of this seminar is to convey the ability to independently familiarize with a given technical topic, identify all relevant aspects and sum up the results in a presentation.
Brief description course	In the seminar „Design of Electronic Systems and Microsystems“, the students carry out a literature und Internet research on a given topic under the supervision of the research assistants, and prepare a short text (approximately a 10-page composition) as well as a 30-minute presentation to introduce the topic for the fellow students.
Contents	In this course the students shall learn how to prepare and present a study on a predefined topic out of the area of electronic systems and Microsystems. Today, the ability to carry out such tasks is expected from an engineer as a matter of course. The only way to learn how to carry out research tasks at the university is in the context of such seminars. By arrangement, at the beginning of each semester a pre-discussion takes places. Thereby, not only the objectives of the seminar are explained, but the topics are also disclosed and the decision regarding a topic is made. The actual working time (research of relevant literature, generation of written work, and the preparation of the presentation) amounts to 2-3 months. The presentations take place nearing the end of the semester in the seminar room of the institute. The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German or English
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the composition and the presentation.
Course form	Seminar
General remarks	Current information can be found on the ITIV webpage (www.itiv.kit.edu).

Course name	**Optical Engineering**
Course code	**23629**
Associated Exercise	23631
Lecturer/ Institute	Prof. Stork / ITIV
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	none
Objectives	By the end of this lecture, a student will be able to understand an optical system specification, explain the meaning of the specified properties, and develop possible solutions for a simple design problem.
Brief description course	Foci of the lecture are the methodical and physical fundamentals that are needed for the design and the development of simple optical systems. Using examples from practical experience the applications and limitations of the introduced techniques are presented.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is partly presented and discussed during lecture hall exercises, partly the students are tutored how to use algebraic and numerical software to find the solutions during the exercise hours.

Contents

Lecture

The course teaches the practical aspects of designing optical components and instruments such as lenses, microscopes, optical sensors and measurement systems, and optical storage systems (e.g. CD, DVD, HVD). During the course, the layout of modern optical systems is explained and an overview is given over available technology, materials, costs, design methods, as well as optical design software.

At first the phenomena of light refraction and reflection are introduced to the students using the concepts of ray-optics. Based on these fundamentals, the functionality of optical elements like lenses and parabolic mirrors, as well as of multi-element imaging systems like telescopes, microscopes or the human eye are explained and methods like the ray-transfer matrices are presented that can be used to calculate the properties of these multi-element systems and to describe the light propagation inside of these systems.

After a ray-optical introduction of imaging errors (aberrations), the transition from the ray- to the wave-optical representation of light is made and the aberrations are alternatively described as wavefront deviations. Applying these concepts, the phenomenon of diffraction is introduced and it is shown that even an error-free imaging system has only a limited resolution because of the always present diffractive effects. This then leads to the topics of Fourier optics and the representation of optical systems as LSI-systems (linear, shift-invariant systems) with the transfer function MTF and the “point response” PSF.

In the concluding chapters, the field of diffractive optics is discussed thoroughly, starting from the different types of diffraction gratings, to the functionality of diffractive lenses, to the basic principles of holography.

Exercises

To accompany the lecture material, assignments will be given out and partly discussed during the bi-weekly exercises, partly the students will be supported in finding a solution to the assignments during the exercise hours using standard mathematical software like Maple or Matlab to give them a first introduction to the use of this software and to also show them its strengths and weaknesses.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org Literature: E. Hecht: "Optics", Addison Wesley, 1987; Meschede, D.: "Optics, Light and Lasers", Wiley-VCH, 2007;
Language	English
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination
Course form	Lecture and exercises
General remarks	The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Seminar: How to Invent and Apply for a Patent**
Course code	**23633**
Lecturer/ Institute	Prof. Stork / ITIV
Credit Points	3
Semester hours	2
Term	Winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fun with new ideas.
Objectives	The goal of the seminar is to acquaint basic knowledge on the German and international patent system as well as to learn key issues and concepts in the process of writing a patent application.
Brief description course	To pen a written patent application.
Contents	From many publications of the last few years, we know that Germany is falling behind its competitors on the world market in the patent sector. This has already led to significant disadvantages of German companies on the world market. Recently the situation is getting better but Know-how of the patent system is still only rarely found among engineering alumni. Already during their studies, engineers as future inventers should get insights into the patent systems and learn how to invent and how to write and file a patent application In the first hours the basics of the patent rules for German, European and world patents are introduced. Then some methods for inventing are discussed and exercised in a brain storming process. After finding some ideas the students search in CD and Internet patent data basis trying to find out whether the idea is new or not. If the idea seems to be new, the students are writing patent applications to the German patent office. The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the self-written patent application.
Course form	Seminar
General remarks	Current information can be found on the ITIV webpage (www.itiv.kit.edu).

Course name	**Praktikum Entwurfsautomatisierung**
Course code	**23637**
Lecturer/ Institute	Prof. Klaus Müller-Glaser / ITIV
Credit Points	6
Semester hours	4
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fundamentals of Electronic Systems Design (e.g. SAE, course code 23606, HSO, course code 23619 and HMS, course code 23608).
Objectives	The laboratory gives a practical insight to the cycle of FPGA designs. Using modern design tools, typical design steps on various abstraction levels are carried out and practiced.
Brief description course	In two person teams during several meting the students will familiarize with design complex hardware/software systems. Beginning with simply finite state machine, thru processor design to a real power window control of an S-Class Mercedes.
Contents	Laboratory

The laboratory includes an introduction to the hardware description language VHDL as to become familiar with modern development-, synthesis- and simulation tools like Xilinx Design Environment, ModelSim or MatLab Stateflow that are used in industry. The results of the exercises are verified on real devices and targets such as coffeemaker or a control unit for a car window lift of a Mercedes limousine, for example. This provides in a small scale a complete development cycle as it is known from the real life and demanded from the industry.

The course is basically divided in several parts with different foci. According to these steps the abstraction level of the respective exercises increases steadily.

The lab starts on a very low level by programming a control unit for a commercial, but simple coffeemaker, which will later be tested in a real automaton. Based on this first exercise the coffeemaker control is then reprogrammed in VHDL – as a direct comparison between two possible solutions – and so secondly serves as a perfect introduction to VHDL.

In the next step of the course, a more complex design of a parametrizable RISC-CPU has to be realized in VHDL and is also programmed in Assembly language. Afterwards the entire design is simulated with ModelSim and so the basic function of a CPU can be followed in an easy understandable way. In order to bridge to modern CPUs, the design is extended by a pipeline stage and its effects are observed in further simulation runs.

The following exercises are based on the 32 bit LEON3-processor core with a SPARC® compatible integer unit. To become familiar with the processor core and its peripherals the students have to realise their own I/O-modules that connect to the above bus and provide digital inputs and outputs. Additionally interfaces to a LCD-module and an external CAN-controller device have to be developed. After finishing the hardware, the programming of the LEON3 processor is substance of the lab. Here C-programs for the platform are written to provide access to the previously developed and synthesised hardware modules. The compilation is done by a GNU C-compiler, generating the object files, which are downloaded and tested on the real target.

	In the last step of the lab a window lift control unit based on state charts using Matlab/Statflow has to be realised that can be run on the student's self developed control units. After the implementation is done, C-code is generated from the state charts, compiled together with a framework and downloaded on the LEON3-processor system. The test is performed on a real window lift of a Mercedes S-class car. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.estudium.org
Language	German
Examination	Written (see actual document "Studienplan" and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Laboratory
General remarks	Current information can be found on the ITIV (www.itiv.kit.edu) webpage.

Course name	**Software Engineering Laboratory**
Course code	**23640**
Lecturer/ Institute	Prof. Müller-Glaser / ITIV
Credit Points	6
Semester hours	4
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Knowledge about Systems and Software Engineering (23605) and Software Engineering (23611); C,C++
Objectives	The goal of the laboratory is the communication of the embedded software development the so-called “software engineering” to the students. In addition apart from the employment of the programming languages C/C++, fundamental questions such as e.g. SW-debugging, version management, treatment of software projects in teams and re-use are covered. State of the art topics, like object-oriented analysis and design are treated in different tasks on the basis of the “Unified Modeling Language” (UML) and software “CASE” tools.
Brief description course	The laboratory is based on a “real world” example from industry. The task will be the design and implementation of a firmware on a FPGA (reconfigurable rapid prototyping) platform, which finally controls a sensor-actuator-unit. The work will be accomplished in teams. Commercial CASE (computer-aided software engineering) tools support the development process.
Contents	The students will implement a firmware on a reconfigurable rapid prototyping platform, which finally controls a sensor-actuator-unit (a robot arm). Hardware, device drivers and a software API (application programming interface) will be provided. The target application is a chemical analysis scenario executed by this robot stage, which is provided by a cooperating industrial partner. The robot is capable to move its arm in three degrees of freedom to inject chemical samples. The rapid prototyping (RP) system is remotely controlled through LAN. A standard FPGA based state-of-the-art RP system is introduced, so that students have the chance to reuse their knowledge from lectures dealing with System-on-Chip (SoC) or RP. This choice has also supported an integrated perception of embedded systems including hardware knowledge. Since the assignment is industrial project oriented, which include accurate process characteristics, the students will be given the system requirements in the beginning of the Laboratory. Information is given such as the available API, IO specifications as well as functional requirements of the application. Also timing and precision constraints are formulated. The software design pictures the software requirements in a UML model. C++ code will be generated from this graphical representation. During the implementation phase of the project, the generated code needs to be extended, adopted and refined according to feedback of a windows simulation environment. Of great importance are well written software tests such as unit test cases in the phase of software development. Tests have to be continuously expanded in the same manner as the C++ code evolves. When succeeding with these steps, the sources will be compiled for the target system and uploaded on the PowerPC Processor hard macro that is located on the Virtex2pro FPGA of the RP system.

As a result students gain competences with practical aspects of object oriented programming for embedded systems. On the other hand, the laboratory is focused on the achievement of a global understanding of hardware and software interaction and the potential of reconfigurable platforms.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org and www.itiv.kit.edu
Language	German
Examination	Oral: two oral reviews during the laboratory are followed by a concluding oral examination (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	The grades result from the combination of the cooperation within the laboratory, the 2 evaluations during the laboratory and the final oral examination.
Course form	Laboratory
General remarks	Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium teaching platform (www.estudium.org).

Course name	**System Design under Industrial Constraints**
Course code	**23641**
Lecturer/ Institute	Dr.-Ing. Manfred Nolle / ITIV
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basic knowledge of hardware and software design
Objectives	The goal of this lecture is to provide a realistic picture of realisable methods and techniques.
Brief description course	The lecture provides knowledge of the phase-oriented development process on one side and tools of project management on the other side.
Contents	The two focal points of the lecture are the phase-oriented procedure for development of computer systems for safety-critical real-time applications and the organizational implementation, the project management of such developments. The avionics serves as an example of increased demands for quality, cost-conscious and timely implementation of the development of such systems. The first part of the lecture will start with the explanation of typical requirements for avionics systems. The development process is divided into phases: what are the activities and goals of each phase, how to close a phase, which documents are to create, and how to complete the development. First, the life cycle of a product is presented. This leads to the requirements for a product development, taking into account superior rules and regulations. Next, the concept of quality in the context of a hardware / software development process and the resulting quality management is introduced. Based on this the phased development process is presented, which is specified in regards of the number and content of the phases, the required reviews and documentation. The second focus "project management" covers in detail the project-oriented implementation of a development with the following themes, with the tasks of the project manager in the foreground. Building on the introduction of the term project the task of the project organization to solve the conflict between the goals of quality, cost and schedule is presented. The techniques and time management for planning, management and control are in the foreground. Finally, the issues of communication and intercultural project management are covered. The topics are based on numerous examples and experience reports from the field shown. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.estudium.org
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Lecture
General remarks	The course takes place as a block lecture. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teachingplatform (www.estudium.org).

Course name	**Systems Engineering for Automotive Electronics**
Course code	**23642**
Associated Exercise	23644
Lecturer/ Institute	Prof. Dr.-Ing. Bortolazzi / ITIV (Porsche)
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Participation in the lectures SAE (23606) and SE (23611) is advised
Objectives	The goal of the lecture are knowledge and insight in the systematic development process of electric and electronic systems and architectures in the field of automotive technology and car industry as well as the utilized tools which support the systematic development. A further goal is the tool supported modeling of electric and electronic architectures in the domains functional modeling and physical modeling.
Brief description course	The lecture conveys knowledge concerning methods, techniques and procedures supporting the development phases of electric and electronic systems for cars.
Brief description exercises	In the laboratory / tutorial, a simple and customer related function of a modern car is modeled using a state of the art tool for the modeling of electric and electronic architectures for cars. This involves the modeling of a functional and physical proposal as well as the evaluation of this proposal.

Contents

Lecture

At the beginning, the development of electric and electronic systems of cars is facilitated based on technological and brand specific trends, development processes, process requirements, methods and tools, overview of approaches for solving problems, as well as an overview of further lectures and events.

Dealing with the intended architecture in the car, is presented by the architecture development process, the description of intended car architectures, the hardware- and software-architecture, the networking, the bus systems CAN, Lin, MOST and FlexRay, processor types, standard software modules, the operating system OSEK, standards for diagnosis as well as constraints for the development of architectures (topology, cost, assembly, wiring harness).

An essential part of the lecture is the presentation of development tools which are classified into tools for system development and tools for software development. The tools for system development contain general development processes, requirements for tools, models of computation, requirements engineering, methods and tools for the design of controller as well as methods and tools for the design of distributed systems (TITUS). The tools for software development contain automatic code generation (processes, procedures and tools) as well as automated testing.

The relevance of quality assurance is discussed based on the software quality management system of an OEM.

The topics system design and project management are described by the composition of a development project, the interaction of project management, tools and processes, the risk management as well as the management of suppliers.

Laboratory / Tutorial

During the laboratory, which interleaved to the lecture concerning schedule and content, students work with a state of the art tool for modeling electric and electronic architectures. They model the architecture of a simple function of a modern car. The developed model offers different perspectives to the function. Complexity of modern electric and electronic architectures is facilitated as well as possibilities and methods to stay on top of the complexity.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org and www.itiv.kit.edu
Language	English
Examination	Written: At the end of the lecture, there is a two hour written examination where no means are permitted. (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination. Participation in the laboratory / tutorial is mandatory for the registration to the written examination
Course form	Lecture / Laboratory
General remarks	Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium teaching platform (www.estudium.org).

Course name	**Design Automation Laboratory**
Course code	**23645**
Lecturer/ Institute	Prof. Klaus Müller-Glaser / ITIV
Credit Points	6
Semester hours	4
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fundamentals of Electronic Systems Design (e.g. SAE, course code 23606, HSO, course code 23619 and HMS, course code 23608).
Objectives	The laboratory gives a practical insight to the cycle of FPGA designs. Using modern design tools, typical design steps on various abstraction levels are carried out and practiced.
Brief description course	In two person teams during several meting the students will familiarize with design complex hardware/software systems. Beginning with simply finite state machine, thru processor design to a real power window control of an S-Class Mercedes.
Contents	Laboratory

The laboratory includes an introduction to the hardware description language VHDL as to become familiar with modern development-, synthesis- and simulation tools like Xilinx Design Environment, ModelSim or MatLab Stateflow that are used in industry. The results of the exercises are verified on real devices and targets such as coffeemaker or a control unit for a car window lift of a Mercedes limousine, for example. This provides in a small scale a complete development cycle as it is known from the real life and demanded from the industry.

The course is basically divided in several parts with different foci. According to these steps the abstraction level of the respective exercises increases steadily.

The lab starts on a very low level by programming a control unit for a commercial, but simple coffeemaker, which will later be tested in a real automaton. Based on this first exercise the coffeemaker control is then reprogrammed in VHDL – as a direct comparison between two possible solutions – and so secondly serves as a perfect introduction to VHDL.

In the next step of the course, a more complex design of a parametrizable RISC-CPU has to be realized in VHDL and is also programmed in Assembly language. Afterwards the entire design is simulated with ModelSim and so the basic function of a CPU can be followed in an easy understandable way. In order to bridge to modern CPUs, the design is extended by a pipeline stage and its effects are observed in further simulation runs.

The following exercises are based on the 32 bit LEON3-processor core with a SPARC® compatible integer unit. To become familiar with the processor core and its peripherals the students have to realise their own I/O-modules that connect to the above bus and provide digital inputs and outputs. Additionally interfaces to a LCD-module and an external CAN-controller device have to be developed. After finishing the hardware, the programming of the LEON3 processor is substance of the lab. Here C-programs for the platform are written to provide access to the previously developed and synthesised hardware modules. The compilation is done by a GNU C-compiler, generating the object files, which are downloaded and tested on the real target.

In the last step of the lab a window lift control unit based on state charts using Matlab/Statflow has to be realised that can be run on the student's self developed control units. After the implementation is done, C-code is generated from the state charts, compiled together with a framework and downloaded on the LEON3-processor system. The test is performed on a real window lift of a Mercedes S-class car.

The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Online material is available on: www.estudium.org
Language	English
Examination	Written (see actual document "Studienplan" and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination
Course form	Laboratory
General remarks	Current information can be found on the ITIV (www.itiv.kit.edu) webpage.

Course name	**Optical Design Lab**
Course code	**23647**
Lecturer/ Institute	Prof. Stork / ITIV
Credit Points	6
Semester hours	4
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Fundamentals of optics (attending the lecture „Optical Engineering“ during the same term is highly recommended)
Objectives	During that course, a student will learn to apply the theoretical optics knowledge he has acquired to design an optical system which is optimized regarding some given constraints with a typical Optical Design software.
Brief description course	In this lab course, the participating students will have the opportunity to gain hands-on experience with two software tools for the design of optical elements and systems that are widely used in industry and to expand their theoretical knowledge about Optical Engineering.
Contents	The Optical Design Lab consists of 9 assignments that have to be finished during the course of the term. The focus of the first 7 assignments is on the design und the optimization of optical imaging systems, which are done using the software “OSLO”. The last two assignments are from the field of illumination design, here the software “LightTools” is used. After an introductory assignment that allows the students to familiarize with the operation of the software, the four following assignments are about the simulation as well as the software-aided design and optimization of optical imaging systems (e.g. eye, telescope, microscope). The theoretical part of these assignments is focussed on the different quantities to measure imaging quality (aberrations, Optical Path Difference, Modulation Transfer Function). The two following assignments with OSLO have their main focus on fibre-optics / fibre-coupling of laser light and in the area of diffractive optics. The lab course concludes with two assignments from the area of illumination design. Here the students will employ the software LightTools to design, among others, the backlight for a LCD and a car headlight. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.estudium.org; Literature: E. Hecht: "Optics", Addison Wesley, 1987; H.-P. Herzig (Ed.): Fundamentals of Microoptics, Elements, Systems and Applications, Taylor & Francis, 1997; OSLO Optics Reference Manual, downloadable from www.lambdares.com
Language	English
Examination	Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the oral examination. The topics of the oral exam stem from the theoretical basics conveyed in the accompanying documents as well as from the actual assignments.
Course form	Lab course
General remarks	Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium-teaching platform (www.estudium.org).

Course name	**Electronic Devices and Circuits**
Course code	**23655**
Associated Exercise	23657
Lecturer/ Institute	Prof. Siegel / IMS
Credit Points	6
Semester hours	4
Term	Summer term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Prerequisites	23256 (Linear Electronic Networks)
Objectives	To understand the function and operating principles of pn junctions, pn- and zener diodes, bipolar and field-effect devices, basic analog and digital circuit components including single stage and operational amplifiers. To understand device parameters and operating principles, analyze and calculate single-stage amplifiers, CMOS and multi stage amplifiers, differential amplifier and output stages as well as operational amplifier applications. To understand and apply dc and ac device and circuit models in circuit design and understand the constraints. To understand and apply all basic digital circuits (inverter, NAND, NOR, tri state inverter and transmission gates), sequential logic circuits RS-, D- and JK- flip flops at counters, frequency dividers and shift registers. To understand and apply digital-to-analog and analog-to-digital converters
Brief description course	Fundamental lecture on electronic devices and circuits design. Focuses of the lecture are active devices for basic analog and digital circuits. Based on device operation, implementation of analog single and multistage amplifiers based on bipolar and field effect transistors and basic digital logic gates and the design of sequential logical circuits based on these gates are discussed. The basics of analog-to-digital and digital-to-analog converters will be introduced.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises. Subsequently more dedicated assignments in form of tutorial sessions, in form of small study groups, are offered to deepen the understanding of the curriculum's as well as the exercises contents.
Contents	Lecture Notions and basic numerical tools Passive circuits (R, C, L) Properties of diodes and transistors Transistor equivalent circuits for dc and ac Circuits with common emitter, base and collector Multistage amplifier circuits with and without feedback Basic characteristics of operational amplifiers Typical applications of operational amplifiers Introduction to digital electronics Considerations of integrated circuit engineering Basic logic circuits with bipolar and field-effect devices Detailed description of n-MOS-, p-MOS- and CMOS-circuits Flip-flops, counters and Schmitt-triggers Multiplexer and demultiplexer, Main principles of analog-to-digital and digital-to-analog conversion. Exercises

	To accompany the lecture material, assignments and the corresponding solutions will be given out and discussed during lecture hall exercises. Furthermore tutorials are offered for groups up to 16 students to deepen the understanding of the curriculum and methods taught at lecture. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.ims.kit.edu Literature: a booklet is available for free to all students at the first lecture
Language	German
Examination	Written (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade	Grades result from the written examination and form homework. 90% examination, 10% Homework
Course form	Lecture, Exercises, and Tutorials
General remarks	The course comprises of the interleaved lecture blocks, exercises, and tutorials. Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**VLSI Technology**
Course code	**23660**
Lecturer/ Institute	Prof. M. Siegel / IMS
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	23655 (Electronic Devices and Circuits)
Objectives	To understand basic silicon technology: wafer preparation; mask generation techniques; lithography; diffusion process; ion implantation; oxidation; etching techniques - wet etching and plasma etching; thin film deposition - epitaxial growth, chemical vapor deposition techniques, metallization; To understand nMOS and CMOS technology steps and advanced process integration for CMOS, To understand and apply scaling techniques of CMOS devices and short channel effects, To understand future trends in VLSI technology, technology limitations and possible new devices for the future.
Brief description course	CMOS is the standard technology for fabrication of very-large scale integrated circuits. The lecture covers the fundamental knowledge of all processes for fabrication of integrated CMOS circuits. The mutual dependence of devices properties and operation on fabrication issues will be discussed. Finctional basic cells will be introduced and discussed in the framework of scaling approaches. In detail, short channel effects will be introduced. The basics of the semiconductor roadmap will be covered.
Contents	ITRS - Roadmap CMOS process Silicon – the material of VLSI technology Basics of manufacturing integatred circuits Thermal oxidation of silicon, ion implantation, diffusion processes Thin film CVD and silicon epitaxy Lithography, chemical and physical patterning N-well CMOS process Characteristics of short channel MOSFETs Latch-up, twin well process Ultra-Large Scale Integration (ULSI) Scaling rules for MOS devices Local oxidation of silicon (LOCOS) Short channel effects Power consumption Overview of worldwide research activities for future devices Nano-MOSFET The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Transparencies Hilleringmann, Ulrich, Silizium-Halbleitertechnologie, B.G. Teubner Verlag Giebel, Thomas, Grundlagen der CMOS-Technologie , B.G. Teubner Verlag
Language	German
Examination	Oral
Formation of grade	Examen
Course form	Lecture
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**Analog Circuit Design**
Course code	**23664**
Associated Exercise	23666
Lecturer/ Institute	Dipl.-Ing. E. Crocoll / IMS
Credit Points	04. Mai
Semester hours	3
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master

Objectives

Lecture To understand the behaviour of integrated BJTs and FETs, analysing the large and small signal characteristics of the devices. To understand the design steps of analog amplifier stages. To understand the design of bias circuits; current sources, current mirrors, PTAT and CTAT circuits.To understand the frequency response of operational amplifiers and feedback circuits.To understand the noise sources of integrated devices and circuits. Exercises To understand the essential design rules for analog circuit design.To design an operational amplifier step by step using the CadenceÒ Virtuoso full custom design environment. To understand and use the CadenceÒ simulation tools To understand and use the CadenceÒ layout tools to do a cell layout of the designed operational amplifier.

Brief description course

On the basis of an operational amplifier all steps of analog integrated circuit design is demonstrated using well-known common circuits. After deepen the properties of bipolar and field effect devices a stepwise design of different types of amplifier stages is discussed as well as frequency response and stability of feedback amplifiers. Finally the noise in integrated circuits is analyzed considering the various sources of electronic noise.

Brief description exercises

Supporting the lecture, assignments to the curriculum are distributed. Using Cadence™ tools, common analog circuits are designed, simulated and optimized.

Contents

Lecture

Integrated Circuits (Bipolar, MOS)
Design of Integrated Operational Amplifiers
Structure and Design of Input Stages
Structure and Design of Amplifier Stages
Structure and Design of Output Stages
Structure and Design of Bias Circuits
Frequency Response and Compensation
Noise in integrated Circuits
Analog Design Layout Rules
Exercise
Getting familiar with the CadenceÒ Virtuoso full custom design environment.
Design and simulation of parts of an operational amplifier
Design of a temperature compensated bias circuit
Layout of the differential input stage of the amplifier
The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes	Lecture slides are provided for download. Analysis and Design of Analog Integrated Circuits, Gray, Hurst, Lewis, Meyer, John Wiley & Sons, Inc - Analog Integrated Circuit Design, David A. Jones, Ken Martin,John Wiley & Sons, Inc - Analog Design Essentials, Willy M.C. Sansen, Springer
Language	German
Examination	oral
Formation of grade	Grades result from the oral examination. Prerequisite: submission of a written protocol of all exercise results
Course form	Lecture, Exercises
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**Nanoelectronics**
Course code	**23668**
Lecturer/ Institute	Prof. Siegel / IMS
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	To understand the reasons behind Moore’s Law and CMOS scaling. To understand the electrical properties of silicon devices as they are scaled below 100nm. To understand principles of nano-devices (SET, Coulomb blockade, nano flash) To understand resonant tunneling devices. To understand superconducting nano sensors and devices (SPD, Nano-JJ). To understand the various methods to fabricate and measure nanoscale features. To understand nano devices for quantum computing.
Brief description course	Based on Moore’s lwa and fundamental physical principles the limits of VLSi technology are discussed. Starting from a detailed quantum-mechanical treatment of electron transport, different nano-devices will be discussed in detail.
Contents	Moore's Law Microelectronic Roadmap Characteristics of Electrons Limits of Silicon Technology New ultimate MOSFET's (Nanotubes, organic FET) Nanoelectronic Devices Single-electron Transistor (Coulomb blockade, Nano-Flash) Nanoscaling Memory Devices Resonant Tunnelling Devices Superconducting Nanostructures (Nano-JJ, SPD) Molecular electronics Characteristics of Nanostructures Devices and Circuits for Quantum computers The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.ims.kit.edu
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination

Course name	**Laboratory Nanoelectronics Technology**
Course code	**23669**
Lecturer/ Institute	Prof. Siegel / IMS
Credit Points	6
Semester hours	4
Term	Winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Lectures 23660 and 23668
Objectives	To learn basic technological skills needed in thin film and chip technology. To learn basic sample preparation and measurement skills. To understand how to carry out and analyze measurements. To apply and deepen the knowledge from lectures about VLSI technology and nanoelectronics. To develop an understanding of the differences between theory and real measurements.
Brief description course	In this laboratory course the theoretical knowledge of lectures will be applied in technological processes. The students will learn the basics in working at technological equipment to assemble integrated circuits. After a short introduction the students will independently work on tasks in the clean room and the technology laboratory for superconducting device development.
Contents	Thin film deposition by sputtering and evaporation. Photolithography in the clean room, positive and negative processes. Production of thin film niobium samples, Josephson junctions and overlay capacitors. Measurements at low temperatures (in a liquid helium bath). Parameter dependent measurements of: Critical temperatures and residual resistivity ratios of thin films / IV-characteristics and Fraunhofer figures of Josephson junctions / capacities, resistances and areas of overlay capacitors. Analysis and interpretation of the measurement results. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Lecture Handouts
Language	German and/or English – upon the choice of the students
Examination	Oral (final presentation)
Formation of grade	Grades result from the performance and the presentation
Course form	Laboratory
General remarks	The laboratory will take place as a two week block course. Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**Laboratory Adaptive Sensor Electronics**
Course code	**23672**
Lecturer/ Institute	Prof. Siegel / IMS
Credit Points	6
Semester hours	4
Term	Winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	To understand programmable systems-on-chips (SOCs) using mixed-signal arrays. To understand implementation of analog and digital-logic functions at programmable devices using modern integrated hardware and software development environment. To give students a hands-on experience in signal acquisition, processing and conditioning. To understand design, implementation, and debugging of analog and digital circuits using computer-aided design tools and programming very closely to the underlying hardware. To work on implementation of complex circuits using programmable mixed signal arrays (analog and digital)
Brief description course	This laboratory course introduces "Programmable System-on-Chip" devices and "Integrated Development Environment" Software from Cypress and the use of internal analog and digital blocks to design signal conditioning systems for different sensor types. To build a human interface for interacting and displaying the measurement results on a computer screen, LabView software by Ni is used.
Contents	Familiarization with the Cypress PSoC-Designer™ / -Express™ and National Instruments Labview™ development systems. Introduction to Labview and design including implementation of an interface between digital data and human accessible information. Introduction to PSoC-Designer and PSoC-Express Development and implementation of applications for temperature, humidity and barometric pressure measurement using different sensor readout principles and data evaluation in Labview. Development of a controllable fan regulation. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.ims.kit.edu
Language	German
Examination	Written and oral
Formation of grade	Grades result from average value of marks for homework, performance, and oral short-examination of all projects
Course form	Laboratory
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**Laboratory FPGA based Circuit Design**
Course code	**23674**
Lecturer/ Institute	Dipl.-Ing. E. Crocoll / IMS
Credit Points	6
Semester hours	4
Term	Winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	To understand FPGA based development systems. To understand to implement logic functions at programmable logical devices using modern development and simulation tools. To give students a hands-on experience in design, implementation, and debugging of digital circuits using computer-aided design tools for schematic capture and simulation. To work on implementation of complex circuits using programmable array logic.
Brief description course	In this laboratory course deals with FPGA devices and the associated software development system to study the available tools for design, simulation and debugging of complex logic systems. All designed logical functions are checked using an evaluation board.
Contents	Familiarization with the Altera Quartus development system Design, simulation and test of a Viterbi decoder for different design entries (VHDL, schematic entry, Altera design wizard) Design, simulation and test of digital filter circuits (Low pass, high pass, notch, pass band) The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Course Handouts, Altera Cyclone II Device Handbook
Language	German
Examination	Oral, Written
Formation of grade	Grades result from average value of marks in performance and written report on all projects
Course form	Laboratory
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**Superconductive Technologies**
Course code	**23676**
Lecturer/ Institute	Prof. Noe / IMS (ITEP, KIT)
Credit Points	3
Semester hours	Bachelor/Master
Bachelor/ Master	Bachelor/Master
Compulsory course	Compulsory course field of study 15
Elective course	Elective course for other Fields of Study
Objectives	Understand basic phenomena of superconductivity Understand cause of AC loss and estimate AC loss in superconductors Understand basic stability of superconductors Geometry, characteristic and fabrication routes of technical superconductors To understand principle of nuclear fusion and fusion magnet technology Set-up and principle of high field magnets Understand basics of current leads to low temperatures
Brief description course	Superconductivity has many applications in medicine, science, electrical engineering, electronics, transport and mechanical engineering. For example, future fusion power plants are not possible without large superconducting magnets for guiding the plasma. Since the discovery of high-temperature superconductivity in 1986 R&D in superconductivity is rapidly increasing.
Contents	Basics of superconductivity Superconducting phenomena AC loss in superconductors Electrical and thermal stability of superconductors Manufacturing and Characteristics of superconductors Electro-mechanical characteristics of superconductors Fusion magnet technology High field magnet technology Design of current leads Excursion The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.ims.kit.edu
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage. At the end of the course an excursion is planned.

Course name	**Detectors for Applications in Space and Astronomy**
Course code	**23678**
Associated Exercise	Lecture corresponding exercises
Lecturer/ Institute	PD. Dr. Ing. Scherer / IMS
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Basics in electronics and physics
Objectives	To understand the frequency ranges covered by different sources in space; principles of detection of light, radiowaves, infrared and THz-Radiation, X-ray and gamma-radiation; modulations; To understand functionality and fabrication of radiation detectors; semiconducting detectors, heterodyne-mixers, bolometers Development of electronic read-out circuits for detectors To learn RF system integration on radio antennas and satellites; cryotechnology, low noise amplifiers, filters Knowledge of world wide instrumentation in large radioastronomy projects (on earth and in space)
Brief description course	The lecture provides the knowledge of functionality, fabrication and system integration of modern integrated detector circuits for applications in astronomy/astrophysics and for space missions. The covered frequency range is 1 GHz up to several THz. High speed semiconducting components as HEMTs and Schottky-diodes and superconducting detectors as SIS-mixers and Hot-Electron-Bolometers (HEBs) as well with dimensions in the micro- and nanometer range are the main concern of this lecture. The integration of the detectors in a complete measurement system with antennas, amplifiers, filters and the cryotechnical environment is demonstrated especially on base of international large terrestrial and space research projects. The function and the assembly of X-ray detectors on base of TES/SQUIDs and WIMP- and neutrino detectors for cosmological considerations are discussed. The lecture is a continuation of the lecture “Nanoelectronics”.
Contents	· Astrophysical sources in space, frequency ranges · Semiconducting detectors · SIS-mixers for radio telescopes · Hot-Electron-Bolometer mixers (HEB) · System integration / RF techniques (Read-out circuits, amplifiers, filters, etc…) · RF filter MEMS · Existing instruments and projects worldwide · Recent large future projects (SOFIA, HERSCHEL, ALMA) · Detectors for X-ray detection (TES/SQUID) and particle astrophysics · Kinetic inductance detectors (KID) · Neutrino and WIMP detectors The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.ims.kit.edu
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination

Course form	Lecture
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**Seminar Embedded Circuits and Detectors**
Course code	**23679**
Lecturer/ Institute	Prof. Siegel / IMS
Credit Points	3
Semester hours	2
Term	Winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	Based on technical literature a presentation on a new scientific technical topic has to be carried out. Prepare a presentation (about 40 minutes) about a specific scientific or technical topic and a follow-up question-and-answer session. To participate in the discussion and ask questions. To lead one presentation and the follow-up class discussion.
Brief description course	Seminar, small group discussion and Colloquia on topics related to the engineering mission statement and goals. This course is required for all graduate students in the area of micro- and nanoelectronics.
Contents	Topics out of: Low power low voltage design Delta-Sigma modulators Noise in electronic devices and detector circuits Read-out amplifiers for THz detectors Principles of Superconductivity Superconducting detectors Properties of low noise wide band rf amplifiers Properties of quantum devices Josephson effect: properties and applications The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Material is provided by lecturers.
Language	German
Examination	Oral (Presentation)
Formation of grade	Grades result from the presentation performance
Course form	Seminar
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**Superconducting Systems**
Course code	**23681**
Lecturer/ Institute	Prof. Noe / IMS (ITEP)
Credit Points	3
Semester hours	2
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	The lecture contains the basics of superconductivity for engineers and a state-of-the-art overview about superconducting materials and their characteristics. For the most relevant superconducting applications in power systems the function and the state-of-the-art is given.
Brief description course	Superconductivity gives promise to energy transmission without losses. Many scientists and engineers are inspired by this idea since the discovery of superconductivity in 1911. In 1986 the so-called High Temperature Superconductors enable efficient and low cost cooling with liquid nitrogen. Since this breakthrough R&D in superconductivity is rapidly increasing.
Contents	Basics of superconductivity Superconducting phenomena Stability of superconductors and loss mechanism Characteristics and manufacturing of superconductors Superconducting energy transmission Superconducting motors and generators Superconducting transformers Superconducting magnetic energy storage Superconducting magnets Superconducting electronic applications Basics of cryogenics The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.ims.kit.edu
Language	German
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage. At the end of the course an excursion is planned to KIT Campus North (ITEP).

Course name	**Superconductivity in Smart Grid Power Applications**
Course code	**23682**
Lecturer/ Institute	Prof. Noe / IMS (ITEP), Dr. Grilli (ITEP)
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	The lecture contains the basics of superconductivity for engineers and a state-of-the-art overview about superconducting materials and their characteristics. For the most relevant superconducting applications in power systems the function and the state-of-the-art is given.The lecture contains the basics of superconductivity for engineers and a state-of-the-art overview about superconducting materials and devices. Particular attention is given to applications such as cables, fault current limiters, magnets, motors and transformers.
Brief description course	Superconductivity gives promise to energy transmission without losses. Many scientists and engineers are inspired by this idea since the discovery of superconductivity in 1911. In 1986 the so-called High Temperature Superconductors enable efficient and low cost cooling with liquid nitrogen. Since this breakthrough R&D in superconductivity is rapidly increasing.
Contents	Introduction of the course Basics of superconductivity Materials I (low-Tc superconductors) Materials II (high-Tc superconductors) Stability AC losses Simulation and modeling Cables Fault current limiters Magnets, motors, transformers Smart-grids Lab tour The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.ims.kit.edu
Language	English
Examination	Oral
Formation of grade	Grades result from the oral examination
Course form	Lecture
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage. At the end of the course an excursion is planned to KIT Campus North (ITEP).

Course name	**Digital Circuit Design**
Course code	**23683**
Associated Exercise	23685
Lecturer/ Institute	Dipl.-Ing. E. Crocoll / IMS
Credit Points	04. Mai
Semester hours	3
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	To understand the electrical characteristics of digital integrated circuits To understand logic levels, noise margins, power consumption, and propagation delays of digital integrated circuits based on CMOS technologies To understand static and dynamic behaviour of basic logical gates To understand on chip interconnections and parasitics To understand combinatorial logic and sequential logic To understand on chip clock distribution and timing requirements To understand memory cell design, write and read cycles and readout amplifiers
Brief description course	Fundamental lecture in design of digital core cells. Based on CMOS characteristics design rules for standard logical gates are discussed as well as the behaviour of static and dynamic logic cells, combinatorial and sequential logical devices, clock distribution strategies and considerations for layout under specified conditions and rules.
Brief description exercises	Supporting the lecture, assignments to the curriculum are distributed. Using Cadence™ tools, basic digital cells are designed, simulated and optimized.
Contents	Lecture Operation and modelling of CMOS Devices, Device current-voltage characteristics MOS transistor capacitances, Propagation delay, capacitance / voltage dependence CMOS inverter: static voltage-transfer characteristics, Dynamic behaviour, equivalent resistances, propagation delay Logic gates: NAND, NOR: voltage-transfer characteristics Transmission Gates: voltage-transfer characteristics IC interconnect , Interconnect capacitance and resistance Standard complementary CMOS combinatorial logic gates Sequential logic: Flip-flops, latches, registers Clocking and timing , Clock distribution, timing analysis Memory design, SRAM, DRAM, readout amplifiers Exercise Schematic entry, Cadence Analog Artist Layout design rules Layout editing, Cadence VirtuosoXL Circuit parasitics extraction, (DRC, ERC) Design and simulation (dc, transient) of logical gates, Flip flops, PLL (group design projects) The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Lecture slides are provided for download. Online material is available on: www.ims.kit.edu Digital Integrated Circuits, Jan M. Rabaey, Prentice Hall

Language	German
Examination	oral
Formation of grade	Grades result from the oral examination. Prerequisite: submission of a written protocol of all exercise results.
Course form	Lecture, Exercises
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**Seminar Project Management for Engineers**
Course code	**23684**
Lecturer/ Institute	Prof. Noe / IMS (ITP)
Credit Points	3
Semester hours	2
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Key Qualification
Objectives	Understand and apply - project management basics and tools - basics and types of project communication - major steps from specification to contracts - project modifications and claims - basics of project quality assurance
Brief description course	This seminar belongs to the key qualifications within the master study and is a non-technical course within the diploma study of electrical engineering and information technology. Each part is structured in a short introduction followed by group exercises. Practical examples are given in this group exercise.
Contents	Basics of project organisation Project communication and documentation Softwaretools for resource planning Quality assurance Claim management The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	Oral
Course form	Seminar
General remarks	The course takes place on 5 afternoons. Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**Integrated Systems and Circuits**
Course code	**23688**
Associated Exercise	23690
Lecturer/ Institute	Prof. Siegel / IMS
Credit Points	4,5
Semester hours	3
Term	Winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	23655 (Electronic Devices and Circuits)
Objectives	To understand the entire signal path of a mixed signal integrated circuit for analog and digital signal processing To understand signal conditioning of analog sensor signals Filters and sample & hold techniques Analog to digital converters Digital to analog converters Control of actuators Signal processing with microcontrollers and DSP's Signal processing with FPGA's Integrated circuits for analog and digital signal processing
Brief description course	The lecture contains the knowledge for the development and the implementation of modern mixed-signal circuits for sensor signals, digital signal processing and output signals for actuators. The lecture is focused on modern analog circuit design for signal conditioning before analog-digitals conversion. Further filter amplifiers and Sample&Hold circuits will be described. Analog-digital converters are introduced in detail. The different families of the user specific circuits, in particular FPGA and PLD are discussed.
Brief description exercises	The tutorial will engross some lecture content, especially analog and digital filters and also FPGA.
Contents	Concepts for the implementation of integrated “System-on-Chip” solutions with highly integrated circuits on the sensor level, the analog and digital signal processing and the actuator will be discussed. In particular, concepts for the automotive sector are discussed. The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Online material is available on: www.ims.kit.edu
Language	German
Examination	Oral
Formation of grade	oral examination
Course form	Lecture
General remarks	Current information can be found on the IMS (www.ims.kit.edu) webpage.

Course name	**Solid-State Electronics**
Course code	**23704**
Associated Exercise	23706
Lecturer/ Institute	Professor Uli Lemmer / LTI
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor
Compulsory course	Bachelor
Objectives	Fundamentals of quantum mechanics The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German
Examination	written 2h
Formation of grade	Grads results from the written examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Plastic Electronics**
Course code	**23709**
Lecturer/ Institute	Professor Uli Lemmer / LTI
Credit Points	3 + 0
Semester hours	2 + 0
Term	winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Festkörperelektronik
Brief description exercises	No Tutorial
Contents	Outline of the course: 1. Introduction 2. Optoelectronic properties of organic semiconductors 3. Organic light emitting diodes (OLEDs 4. Applications in Lighting and Displays 5. Organic FETs 6. Organic photodetectors and solar cells 7. Lasers and integr The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	English
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**23710**
Course code	Dr. Rainer Kling / LTI
Credit Points	6 + 0
Semester hours	4 + 0
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	Grads results from the written report and the presentation of the work in the colloqium
Formation of grade	Grads results from the presentation
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Solar Energy**
Course code	**23711**
Lecturer/ Institute	Professor Uli Lemmer / LTI
Credit Points	4,5 + 0
Semester hours	3 + 0
Term	winter term
Bachelor/ Master	Bachelor/Master Bachelor/Master
Elective course	For all fields of specification
Brief description exercises	No Tutorial
Contents	Gliederung der Vorlesung: 1. Einleitung 2. Die Sonne als Energiequelle 3. Halbleiterphysikalische Grundlagen 4. Kristalline pn-Solarzellen 5. Elektrische Eigenschaften 6. Optimierung von Si-Solarzellen 7. Anorganische Dünnschichtsolarzellen 8. Thi The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German
Examination	written 2h
Formation of grade	Grads results from the written examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Optoelctronics Lab**
Course code	**23712**
Lecturer/ Institute	Dr. Rainer Kling / Dr. Klaus Trampert / LTI
Credit Points	0 + 6
Semester hours	0 + 4
Term	winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Bachelor The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German or English
Examination	One Report or short oral examination per lab. In total 4 examinations.
Formation of grade	Avarage of 4 notes for the reports
Course form	Lab
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Nanotechnology Lab**
Course code	**23714**
Lecturer/ Institute	Professor Uli Lemmer / Dr. Klaus Trampert / LTI
Credit Points	0 + 6
Semester hours	0 + 4
Term	winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Bachelor The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German or English
Examination	One Report or short oral examination per lab. In total 4 examinations.
Formation of grade	Avarage of 4 notes for the reports
Course form	Lab
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Lighting Technology lab**
Course code	**23715**
Lecturer/ Institute	Professor Cornelius Neumann / Dr. Klaus Trampert / LTI
Credit Points	0 + 6
Semester hours	0 + 4
Term	winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Bachelor
	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German or English
Examination	One Report or short oral examination per lab. In total 4 examinations.
Formation of grade	Avarage of 4 notes for the reports
Course form	Lab
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Nanoscale Systems for Optoelctronics**
Course code	**23716**
Lecturer/ Institute	Dr. Habil. Hans Eisler
Credit Points	3 + 0
Semester hours	2 + 0
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Bachelor
Brief description exercises	No Tutorial
Contents	Interaction of Light with Nanoscale Systems - general introdcution and motivation - nano-metals (Au, Ag, Cu, Al ...) introduction to optical properties mie scattering - artificial quantum structures (semiconductor quantum dots, quantum wires...) - quantum The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Principles of Nano-Optics, L. Novotny and B. Hecht, Cambridge University Press, 2006 • Absorption and Scattering of Light by Small Particles, C. F. Bohren and D. R. Huffman, John Wiley& Sons, INC. 1998 • Principles of Optics, Born and Wolf, Cambridge Univ
Language	German or English
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**23717**
Course code	Professor Cornelius Neumann / LTI
Credit Points	3 + 0
Semester hours	2 + 0
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
	The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**23720**
Course code	23722
Lecturer/ Institute	Professor Cornelius Neumann / LTI
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	winter term
Bachelor/ Master	Master
Elective course	Master
	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German
Examination	written 2h
Formation of grade	Grads results from the written examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Technical Optics**
Course code	**23721**
Lecturer/ Institute	Professor Cornelius Neumann / LTI
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German
Examination	written 2h
Formation of grade	Grads results from the written examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Optics & Photonics Lab (II)**
Course code	**23723**
Lecturer/ Institute	Dr. Klaus Trampert / LTI
Credit Points	0 + 6
Semester hours	0 + 4
Term	winter and summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Bachelor The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	English
Examination	One Report or short oral examination per lab. In total 4 examinations.
Formation of grade	Avarage of 4 notes for the reports
Course form	Lab
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Optoelectronics**
Course code	**23726**
Associated Exercise	23728
Lecturer/ Institute	Professor Uli Lemmer / LTI
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	Summer term
Bachelor/ Master	Bachelor/Master Bachelor/Master
Elective course	For all fields of specification
Prerequisites	Festkörperelektronik The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Light and Plasma Sources**
Course code	**23729**
Lecturer/ Institute	Dr. Rainer Kling / Professor Wolfgang Heering / LTI
Credit Points	3 + 0
Semester hours	2 + 0
Term	winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	Electronic processes and radiation mechanisms in solid state and plasma, Light sources : Halogen lamps, low pressure lamps, HID, LED, Laserdiods
Brief description exercises	No Tutorial
	The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Introduction in the technology of active dispalys**
Course code	**23732**
Lecturer/ Institute	Dr. Michael Becker
Credit Points	1,5 + 0
Semester hours	1 + 0
Term	winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible at http://www.displaymetrology.com. Access-data (user/pwd) are available after registration via eMail.
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Introduction into plasma technologies**
Course code	**23734**
Lecturer/ Institute	Dr. Rainer Kling / Professor Wolfgang Heering /LTI
Credit Points	3 + 0
Semester hours	2 + 0
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	Basic knowledge on plasma technologies for coatings, semiconductor production and lamps
Brief description course	Einführungsvorlesung von den physikalischen Grundlagen zu den Anwendungen der Plasmatechnologie. Wie wird ein IC Prozessor hergestellt, wie funktioniert eine Niederdrucklampe, wie ein Ionentriebwerk….? Die Plasmatechnik umfasst einen riesigen Markt: für
Brief description exercises	No Tutorial The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Optoelctronic measurement technology**
Course code	**23736**
Lecturer/ Institute	Dr. Klaus Trampert / LTI
Credit Points	3 + 0
Semester hours	2 + 0
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Technische Optik
Brief description exercises	No Tutorial
	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Introduction in the technology of passive dispalys**
Course code	**23738**
Lecturer/ Institute	Dr. Michael Becker
Credit Points	1,5 + 0
Semester hours	1 + 0
Term	Summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible at http://www.displaymetrology.com. Access-data (user/pwd) are available after registration via eMail.
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Light Engineering**
Course code	**23739**
Associated Exercise	23741
Lecturer/ Institute	Professor Cornelius Neumann / LTI
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
	The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**optical technology in the automotive**
Course code	**23740**

Lecturer/ Institute	Professor Cornelius Neumann / LTI
Credit Points	3 + 0
Semester hours	2 + 0
Term	summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Lichttechnik
Brief description exercises	No Tutorial
	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Nanoplasmonic**
Course code	**23743**
Lecturer/ Institute	Dr. Habil. Hans Eisler
Credit Points	3 + 0
Semester hours	2 + 0
Term	winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Festkörperelektronik
Brief description exercises	No Tutorial
Contents	Basics, Fundamentals, Volume: 3D-case • General introduction and motivation • Short history of nanoplasmonics • Mawell's Equations • Optical properties of simple metals Nanoscale Surface: 2D-Case • Surface Plasmons and Surface Plasmon Polariton (SPP) The lecturer reserves the right to alter the contents of the course without prior notification.
Language	German or English
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**23744**
Course code	Professor Uli Lemmer / LTI, Professor Michael Siegel / IMS
Credit Points	0 + 6
Semester hours	0 + 4
Term	summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lab
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Photovoltacis**
Course code	**23745**
Lecturer/ Institute	Dr. A. Colsmann / Dr. A. Slobodskyy / LTI
Credit Points	3 + 0
Semester hours	2 + 0
Term	winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Prerequisites	Festkörperelktronik
Brief description course	Due to their properties semiconductors allow for a direct conversion of solar to electrical energy. This lecture covers the basic working principles of solar cells and their application all the way from the established silicon technology to third generati
Brief description exercises	No Tutorial
Contents	Basics of photovoltaic devices Silicon and CIGS solar cells Module/system integration, grid connection Fabrication and new device concepts Organic photovoltaics Other renewable energies Economy and profitability The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Recommended literature: Peter Würfel, Physics of Solar Cells. From Principles to New Concepts, Wiley Peter Würfel, Physik der Solarzellen, Spektrum Verlag Volker Quasching, Regenerative Energiesysteme, Hanser Verlag S. Siebentritt, U. Rau, Wide-gap chalco
Language	English
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Electronic Circuits for Light Sources and Laser**
Course code	**23746**
Lecturer/ Institute	Dr. Rainer Kling, Prof. Dr. W. Heering
Credit Points	3 + 0
Semester hours	2 + 0
Term	summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Objectives	Light Sources and operating systems
Brief description course	Operational modes and principle circuits for plasma radiation sources, LED and solid state lasers
Contents	Electronic Circuits to drive lamps and Laser Basics of coupling of electrical power, circuitry, Characteristics of low- and high frequent ohmic operation Equivalent circuit and electrical parameters Conventional lamp ballasts Transformer and transducto The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	The corresponding documents are avalible under https://studium.kit.edu/
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Light and Display Engineering**
Course code	**23747**
Associated Exercise	23749
Lecturer/ Institute	Dr. Rainer Kling / LTI
Credit Points	3 + 1,5
Semester hours	2 + 1
Term	winter term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
Brief description course	The Light & Display Engineering lecture gives a broad overview of light engineering and display engeneering topics from vision, physiology to displays and further technical applications.
Contents	Overview of lecture: 1. Motivation: Light & Display Engineering 2. Light, the Eye and the Visual System 3. Light in non - visual Processes 4. Fundamentals in Light Engineering 5. Color and Brightness 6. Light Sources 7. Displays 8. Luminaries 9. The lecturer reserves the right to alter the contents of the course without prior notification.
Language	English
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/

Course name	**Photovoltacis**
Course code	**2130935**
Lecturer/ Institute	Professor Michael Powalla / LTI
Credit Points	4,5 + 0
Semester hours	3 + 0
Term	summer term
Bachelor/ Master	Bachelor/Master
Elective course	Bachelor/Master
	The lecturer reserves the right to alter the contents of the course without prior notification.
Lecture notes	Handout during the lecture, including summary.
Language	German
Examination	Oral examination (20 min)
Formation of grade	Grads results from the oral examination
Course form	Lecture
General remarks	You will find the newest Information online on https://studium.kit.edu/