Department of Electrical Engineering
and Information Technology

Description of Modules

1. October 2012
## Electromagnetic Fields and Waves

### Course name
Electromagnetic Fields and Waves

### Course code
23055

### Associated Exercise
23057

<table>
<thead>
<tr>
<th>Lecturer/ Institute</th>
<th>Prof. Trommer / ITE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit Points</td>
<td>6 + 3</td>
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<tr>
<td>Semester hours</td>
<td>4 + 2</td>
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<tr>
<td>Term</td>
<td>Winter term</td>
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<tr>
<td>Bachelor/ Master</td>
<td>Bachelor</td>
</tr>
<tr>
<td>Compulsory course</td>
<td>Bachelor</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>none</td>
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</tbody>
</table>

### 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 as well as online.

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.
<table>
<thead>
<tr>
<th>Language</th>
<th>German</th>
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<tbody>
<tr>
<td>Examination</td>
<td>verbal (see actual document “Studienplan” and notice of the examination office ETIT).</td>
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<tr>
<td>Formation of grade</td>
<td>Grades result from the verbal examination</td>
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<tr>
<td>Course form</td>
<td>Lecture</td>
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Analysis and Design of Multi-Sensor Systems

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 of 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.

Future positioning techniques are discussed, focussing on radar based terrain reference systems as well as image based navigation systems.

Finally the latest methods for system evaluation and testing are presented. These cover software simulation systems, hardware-in-the-loop test systems up to the overall system qualification test.

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
<table>
<thead>
<tr>
<th>Course name</th>
<th>Principles of sensor fusion in integrated navigation systems</th>
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<tbody>
<tr>
<td>Course code</td>
<td>23069</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>PD Dr.-Ing. habil. Jan Wendel / ITE</td>
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<td>Credit Points</td>
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<td>Semester hours</td>
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<td>Term</td>
<td>Winter term</td>
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<td>Bachelor/Master</td>
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<td>Prerequisites</td>
<td>none</td>
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<tr>
<td>Objectives</td>
<td>The goal is to provide an insight into integrated navigation systems.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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.</td>
</tr>
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</table>
| 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 receiver, 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. |
<p>| 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                                                       |</p>
<table>
<thead>
<tr>
<th>Course name</th>
<th>System Optimization Laboratory</th>
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<tr>
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<td>Lecturer/ Institute</td>
<td>Prof. Trommer / ITE</td>
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<tr>
<td>Credit Points</td>
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<td>Semester hours</td>
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<td>Term</td>
<td>Summer and Winter Term</td>
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<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
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<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
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<tr>
<td>Prerequisites</td>
<td>None Attending the lecture “Analysis and Design of Multi-Sensor Systems” is helpful.</td>
</tr>
<tr>
<td>Objectives</td>
<td>The goal is to apply gathered knowledge to practical problems.</td>
</tr>
<tr>
<td>Brief description exercises</td>
<td>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.</td>
</tr>
<tr>
<td>Contents</td>
<td>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.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Notes containing introductive material, detailed experiment descriptions and practice sheets are handed out in a preliminary meeting.</td>
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<tr>
<td>Language</td>
<td>German</td>
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<tr>
<td>Examination</td>
<td>Written and oral.</td>
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<tr>
<td>Formation of grade</td>
<td>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.</td>
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<td>Course form</td>
<td>Laboratory</td>
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<tr>
<td>General remarks</td>
<td>Due to technical reasons, the number of available spaces is higher in the summer term than in the winter term.</td>
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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: oscilloscope, waveform generator, 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
<table>
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<tr>
<th>Course name</th>
<th>Image processing for Navigation</th>
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<tr>
<td>Course code</td>
<td>23090</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Link / ITE</td>
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<tr>
<td>Credit Points</td>
<td>3</td>
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<tr>
<td>Semester hours</td>
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<td>Term</td>
<td>Summer Term</td>
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<td>Bachelor/Master</td>
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<td>Elective course</td>
<td>Bachelor/Master</td>
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<td>Prerequisites</td>
<td>Linear agebra, calculus</td>
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<tr>
<td>Objectives</td>
<td>Basics of image and image sequence analysis</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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.</td>
</tr>
<tr>
<td>Contents</td>
<td>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 online demonstrations. The lecturer reserves the right to alter the contents of the course without prior notification.</td>
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<tr>
<td>Language</td>
<td>German</td>
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<tr>
<td>Examination</td>
<td>Oral</td>
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<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture</td>
</tr>
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</table>
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: Introduction 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

Prerequisites: Bachelor (recommended)

Objectives: The goal is to relay an overview over predictive (Forward looking) driver assistance systems.

Brief description course: This lecture will introduce into the field of “Driver Assistance Systems”, often also named ADAS. 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. After this, the important representatives of ADAS are structured into passive (warning), active (intervening) and safety systems. After a digression into the field of human factors and the requirements put on them by ADAS the lecture closes with an outlook to autonomous vehicle guidance.

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.

Chapter 1 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 initiatives for the reduction of road accident fatalities are explained as well as accident statistics and simulations for the quantification of the accident avoidance potential. Legal questions around ADAS close this chapter.

Systems for vehicle stabilisation and for driver assistance such as wheel slip control, vehicle dynamic control systems, brake assist and the steering assist are preconditions for ADAS and are discussed in the chapters 2 and 3.

Chapter 4 shortly explains infrastructure-based systems for collective traffic guidance.

In chapter 5 passive safety systems restraint systems and pedestrian safety are discussed.

Chapter 6 gives an introduction into machine vision.

Chapter 7 deals with surround sensors such as 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 chapter.
Chapter 8 deals with passive, informing ADAS. At first the ultrasonic-based systems (parking aid, side-view-assist) are explained, followed by video-based systems (night vision, rear-view camera, lane departure warning, pedestrian detection and traffic sign recognition). Secondly follow radar-based systems (lane-change aid, intersection assist and collision warning), and systems based on other sensor technologies such as Lidar and PMD.

In chapter 9 active, intervening, ADAS are discussed. First the adaptive cruise control (ACC), based on Radar- und Lidar-sensors, followed by lane keeping support, the turning assist and smart headlamp control (SHC).

Chapter 10 deals with the safety systems with their huge accident avoidance potential, namely: Predictive brake assist, predictive collision warning and automatic emergency brake.

Chapter 12 is dedicated to future ADAS. At first, the evolution from driver assistance to „Vehicle Motion and Safety“ stands in the foreground with the components of the combination of active and passive safety and the systems for car-to-car and car-to-infrastructure communication. Systems like In-crash-braking and the evasion assist show the way to automatic vehicle guidance.

Lecture notes
Online material is available on:
www.ite.uni-karlsruhe.de/LEHRVERANSTALTUNGEN/prae_fahrer_ws.php.
The material also contains literature links. A Bosch-publication „Fahrerassistenzsysteme“ (only available in German) 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 and Information Technology.

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 exercises' 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.

Lecture notes

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.
<table>
<thead>
<tr>
<th>Course name</th>
<th>Distributed discrete event systems</th>
</tr>
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<tbody>
<tr>
<td>Course code</td>
<td>23106</td>
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<tr>
<td>Associated Exercise</td>
<td>23108</td>
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<td>Lecturer/ Institute</td>
<td>Dr.-Ing. Weickert / IIIT</td>
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<td>Credit Points</td>
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<td>Term</td>
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<td>Elective course</td>
<td>Bachelor/Master</td>
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<tr>
<td>Prerequisites</td>
<td>Probability theory, signals and systems</td>
</tr>
<tr>
<td>Objectives</td>
<td>The goal is to relay theoretical fundamentals.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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.</td>
</tr>
<tr>
<td>Brief description exercises</td>
<td>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.</td>
</tr>
<tr>
<td>Contents</td>
<td>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.</td>
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<tr>
<td>Language</td>
<td>German</td>
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<td>Written (see actual document “Studienplan” and notice of the examination office ETIT).</td>
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<td>General remarks</td>
<td>Current information can be found on the IIIT (<a href="http://www.iiit.kit.edu">www.iiit.kit.edu</a>) webpage. The contents of the course described in this document are subject to modification without prior announcement.</td>
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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: Bachelor

Bachelor/ Master: Bachelor

Prerequisites: 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.

Lecture notes


Language

German

Leistungsnachweis

Written (see actual document “Studienplan” and notice of the examination office ETIT).

Formation of grade

Grades result from the written examination

Lehrform

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.

Language: English
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<td>Course form</td>
<td>Seminar</td>
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</table>
Course name: 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

Objectives: The goal is to convey advanced knowledge in the field of signal processing.

Brief description course: 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.


Language: German
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<td>General remarks</td>
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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.
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. 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 important 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.
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Microcontroller and DSP Processor Laboratory

Course code 23135

Lecturer/ Institute Prof. Dostert / IIIT
Credit Points 6
Semester hours 4
Term Winter term
Bachelor/ Master Bachelor/Master

Prerequisites Basic knowledge out of German courses "Integrierte Signalverarbeitungssysteme" (23125), "Signale und Systeme" (23109), "Messtechnik" (23105) and "Nachrichtentechnik I" (23506) 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: Information technology 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 lecture 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 lecture 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 continuous control circuits;

Analysis of linear control circuits in continuous 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 continuous 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  

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 of 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;
Specification and Design of Discrete Controllers: Classification of control objectives and controllers, Specifications of the controller, Controller design, Implementation, Examples;

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.


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;


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/).

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/).
<table>
<thead>
<tr>
<th>Course name</th>
<th>Stochastic Control Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23171</td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Dr. Kluwe / IRS</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3</td>
</tr>
<tr>
<td>Semester hours</td>
<td>2</td>
</tr>
<tr>
<td>Term</td>
<td>Winter term</td>
</tr>
<tr>
<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Bachelor/Master</td>
</tr>
</tbody>
</table>

**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 Filters, 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.

**Language**
German

**Examination**
Oral

**Formation of grade**
Grades result from the oral examination

**Course form**
Lecture

**Literature:**
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.
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
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.

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 of 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/).
<table>
<thead>
<tr>
<th>Course name</th>
<th><strong>Control of multivariable linear Systems</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23177</td>
</tr>
<tr>
<td>Associated Exercise</td>
<td>23179</td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Dr. Kluwe / IRS</td>
</tr>
<tr>
<td>Credit Points</td>
<td>4,5 + 1,5</td>
</tr>
<tr>
<td>Semester hours</td>
<td>3 + 1</td>
</tr>
<tr>
<td>Term</td>
<td>Winter term</td>
</tr>
<tr>
<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Bachelor/Master</td>
</tr>
</tbody>
</table>

**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.
Supplemental sheets for the lecture are available on the IRS webpage.


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 assess 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.


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.


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).
<table>
<thead>
<tr>
<th>Course name</th>
<th>Batteries and Fuel Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23207</td>
</tr>
<tr>
<td>Associated Exercise</td>
<td>23213</td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Ivers-Tiffée / IWE</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3+1.5</td>
</tr>
<tr>
<td>Semester hours</td>
<td>2+1</td>
</tr>
<tr>
<td>Term</td>
<td>Master</td>
</tr>
<tr>
<td>Compulsory course</td>
<td>Lecture Course “Passive Components”. Basic understanding of electrochemistry and thermodynamics.</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>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.</td>
</tr>
<tr>
<td>Objectives</td>
<td>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.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed.</td>
</tr>
<tr>
<td>Contents</td>
<td>The course provides an overall picture of fuel cells and batteries currently used in innovative environmental and energy conversion applications.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>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).</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Oral (see actual document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>General remarks</td>
<td>The course comprises lectures and exercises. Current information can be found on the IWE website (<a href="http://www.iwe.kit.edu">http://www.iwe.kit.edu</a>).</td>
</tr>
<tr>
<td>Course name</td>
<td>Systematic Product Development in the Sensor Technology</td>
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</tr>
<tr>
<td>Course code</td>
<td>23209</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr.-Ing. Riegel / IWE</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3</td>
</tr>
<tr>
<td>Semester hours</td>
<td>2</td>
</tr>
<tr>
<td>Term</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Compulsory course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>None</td>
</tr>
<tr>
<td>Objectives</td>
<td>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.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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.</td>
</tr>
<tr>
<td>Contents</td>
<td>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.</td>
</tr>
<tr>
<td>Topics covered</td>
<td>Exhaust gas sensors for combustion engine management; Multilayer ceramic technology; Systematic product development methods; Quality management tools</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Online material is available at <a href="http://www.iwe.kit.edu">http://www.iwe.kit.edu</a></td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Oral (see actual document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture</td>
</tr>
</tbody>
</table>
Course name: Materials and Devices in Electrical Engineering

Course code: 23211

Lecturer/ Institute: Dr.-Ing. André 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

Lecture notes: Copies of the slides are available on http://www.iwe.uni-karlsruhe.de

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

<table>
<thead>
<tr>
<th>Course name</th>
<th><strong>Battery and Fuel Cell Systems</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td><strong>23214</strong></td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Dr.-Ing. André Weber / IWE</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3</td>
</tr>
<tr>
<td>Semester hours</td>
<td>2</td>
</tr>
<tr>
<td>Term</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Compulsory course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Batteries and Fuel Cells</td>
</tr>
</tbody>
</table>

**Objectives**  
The participants will gather the knowledge required for the development of battery and fuel cell system by means of selected examples.

**Brief description course**  
In the Lecture Battery and Fuel Cell Systems current fuel cell technology developments will be discussed and system-relevant aspects of fuel cell technology will be covered. The current topics and dates can be found at: http://www.iwe.kit.edu/3159_bbs.php

**Contents**  
- Introduction
- Fuel Cells
- Fuel Cell Systems
- Stack and Cell Technologies
- BoP-Components
- System Design
- Degradation Phenomena
- Batteries
- Battery Systems
- Lithium-Ion Batteries
- alternative electrochemical energy storage

**Lecture notes**  
Copies of the slides are available on http://www.iwe.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
Course name: Seminar Fuel Cell Research Projects

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.

Contents: In this seminar the student has to analyze literature related to a scientific topic in the field of fuel cell research, 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.

Lecture notes: will be provided during the seminar

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
### Seminar Battery Research Projects

**Course name**

Seminar Battery Research Projects

**Course code**

23216

**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 lithium batteries.

**Contents**

In this seminar the student has to analyze literature related to a scientific topic in the field of battery research, 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.

**Lecture notes**

will be provided during the seminar

**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

**Modeling of Electrochemical Systems**

### Course code

**23217**

### Lecturer/ Institute

Dr.-Ing. André Weber / IWE

### Credit Points

3

### Semester hours

2

### Term

Bachelor/Master

### Compulsory course

Bachelor/Master

### Prerequisites

Batteries and Fuel Cells

### Objectives

The participants will gather the knowledge required for the electrochemical modeling of Batteries and Fuel Cells.

### Brief description course

Modeling of electrochemical systems is a multiscale problem. From the charge transfer reaction models considering an atomistic scale to system modeling based on simplified component models that enable a real time simulation different modeling approaches for fuel cells and batteries will be discussed in the lecture. Next to the models, methods to evaluate model parameters from electrochemical measurements as well as questions related to model validation will be discussed. The current topics and dates can be found at: http://www.iwe.kit.edu/3587_3269.php

### Contents

- Introduction
- Transport mechanisms and reactions in electrolytes and electrodes
- Homogenized electrode models for SOFC
- Microstructure reconstruction and FEM electrode models for SOFC
- Cell- and stack-models
- Evaluation of model parameter by electrochemical measurements
- Fuel cell system models
- Homogenized electrode models for LiB
- Microstructure reconstruction and FEM electrode models for LiB
- Electrochemical models for LiB
- Thermal models for LiB

### Lecture notes

Copies of the slides are available on http://www.iwe.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
Course name  Seminar Sensors

Course code  23220

Associated Exercise  none

Lecturer/ Institute  Dr. Wagner / IWE
Credit Points  3
Semester hours  2
Term  Bachelor/Master
Compulsory course  Bachelor/Master
Elective course  Master
Prerequisites  Passive Components [23206]

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 at graduate students in electrical engineering. Students will be trained in acquisition, selection and classification of information in the field of mixed conductors & oxygen-transport membranes and in preparing reports and presenting their results.

Contents  The student has to analyze scientific literature related to the field of mixed-conducting oxygen-transport membranes. The results of this literature study have to be summarized in a paper and presented in a talk.

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
<table>
<thead>
<tr>
<th><strong>Course name</strong></th>
<th>Electrical Engineering for Business Engineers, Part I</th>
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<tbody>
<tr>
<td><strong>Course code</strong></td>
<td>23223</td>
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<tr>
<td><strong>Associated Exercise</strong></td>
<td>23225</td>
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<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Dr. Wolfgang Menesklou / IWE</td>
</tr>
<tr>
<td><strong>Credit Points</strong></td>
<td>02. Mai</td>
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<tr>
<td><strong>Semester hours</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Term</strong></td>
<td>Bachelor/Master</td>
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<tr>
<td><strong>Compulsory course</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Prerequisites</strong></td>
<td>none</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Brief description course</strong></td>
<td>This course introduces undergraduate students of business engineering into the basics of electrical science and engineering.</td>
</tr>
<tr>
<td><strong>Brief description exercises</strong></td>
<td>Supporting the lecture, assignments to the curriculum are distributed. These are solved into additional (voluntary) tutorials.</td>
</tr>
<tr>
<td><strong>Contents</strong></td>
<td>DC: Electrical sources, resistance, circuits, Kirchhoff's law, Fields: Electrical and magnetic fields, dielectrics, inductance, AC: Complex calculus, RLC circuits, filters</td>
</tr>
<tr>
<td><strong>Language</strong></td>
<td>German</td>
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<tr>
<td><strong>Examination</strong></td>
<td>Written (see actual document “Studienplan” and notice of the examination office).</td>
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<tr>
<td><strong>Formation of grade</strong></td>
<td>Grades result from the written examination</td>
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<td><strong>Course form</strong></td>
<td>Lecture and Exercises</td>
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<tr>
<td>Course name</td>
<td>Electrical Engineering for Business Engineers, Part II</td>
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<td>---------------------------------------------------------</td>
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<tr>
<td>Course code</td>
<td>23224</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr. Menesklou / IWE</td>
</tr>
<tr>
<td>Credit Points</td>
<td>04. Mai</td>
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<tr>
<td>Semester hours</td>
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<td>Term</td>
<td>Summer term</td>
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<tr>
<td>Bachelor/ Master</td>
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<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Electrical Engineering for Business Engineers, Part I [23223]</td>
</tr>
<tr>
<td>Objectives</td>
<td>The student is supposed to develop an understanding for the basic terms of electrical engineering.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>This course introduces undergraduate students of business engineering into topics of advanced electrical engineering like electrical instrumentation, semiconductors, communication systems and electrical machines.</td>
</tr>
<tr>
<td>Brief description exercises</td>
<td>Within the lecture, assignments to the curriculum are discussed and are used for preparation to written examination.</td>
</tr>
<tr>
<td>Contents</td>
<td>Electrical instrumentation, Semiconductor Devices, Communication Engineering.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Online material is available at <a href="http://www.iwe.kit.edu">http://www.iwe.kit.edu</a></td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
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<tr>
<td>Examination</td>
<td>Written (see actual document “Studienplan” and notice of the examination office).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the written examination</td>
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<tr>
<td>Course form</td>
<td>Lecture and Exercises</td>
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<tr>
<td>Course name</td>
<td>Sensors</td>
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<tr>
<td>Course code</td>
<td>23231</td>
</tr>
<tr>
<td>Associated Exercise</td>
<td>none</td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Dr. Menesklou / IWE</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3</td>
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<tr>
<td>Semester hours</td>
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<tr>
<td>Term</td>
<td>Bachelor/Master</td>
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<tr>
<td>Compulsory course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Basics in material science, and in electrical and electronics engineering.</td>
</tr>
<tr>
<td>Objectives</td>
<td>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.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Online material is available at <a href="http://www.iwe.kit.edu">http://www.iwe.kit.edu</a></td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Written (see actual document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the written examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture</td>
</tr>
</tbody>
</table>
Course name: Sensors and Actuators Laboratory

Course code: 23232

Lecturer/Institute: Dr. W. Meneskou / IWE

Credit Points: 6

Semester hours: 4

Term: Bachelor/Master

Compulsory 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 of 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

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: Bachelor/Master

Compulsory 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.

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: Batteries and Fuel Cells Laboratory

Course code: 23235

Lecturer/ Institute: Dr.-Ing. André Weber / IWE
Credit Points: 6
Semester hours: 4
Term: Bachelor/Master
Compulsory course: Bachelor/Master
Prerequisites: Batteries and Fuel Cells, Battery- and Fuel Cell Systems

Objectives: The students will learn how to design and apply testing modules and procedures to evaluate the performance of fuel cells and batteries.

Brief description course: This laboratory consists of 8 experiments. These experiments consider design and operating principles of different fuel cell types and systems. The student will acquire skills related to control strategies, testing procedures and measurement data analysis. The tests will be performed on (pre-) series products of well known fuel cell developers as well as on own test benches for single cells. Next to fuel cells additional experiments are related to battery testing and modeling.

Contents: Topics covered:
- Testing of a PEMFC stack
- Testing of a PEMFC system
- Electrochemical characterization of SOFC single cells
- Electrochemical impedance spectroscopy for SOFC
- Modeling of batteries 1
- Modeling of batteries 2
- Testing of batteries

Lecture notes: will be distributed
Language: German
Examination participation and records: the grade is based on: oral examination at the beginning of each experiment, cooperation during the experiment, schriftliche Ausarbeitung der Versuchsprotokolle
Course form: laboratory course
General remarks: max. number of participants: 10 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: Bachelor/Master

Compulsory 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.

| 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 |
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
Prerequisites Bachelor/Master

Objectives
Introduction in scientific working, presentation training

Brief description
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

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, Wheatstone, 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).
<table>
<thead>
<tr>
<th><strong>Course name</strong></th>
<th><strong>Medical Imaging Techniques I</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Course code</strong></td>
<td><strong>23261</strong></td>
</tr>
<tr>
<td><strong>Associated Exercise</strong></td>
<td>/</td>
</tr>
<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Prof. Dössel / IBT</td>
</tr>
<tr>
<td><strong>Credit Points</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Semester hours</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Term</strong></td>
<td>Winter term</td>
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<tr>
<td><strong>Bachelor/ Master</strong></td>
<td>Bachelor/Master</td>
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<tr>
<td><strong>Elective course</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Prerequisites</strong></td>
<td>23275</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>Comprehensive understanding of all methods of medical imaging based on ionizing radiation</td>
</tr>
<tr>
<td><strong>Brief description course</strong></td>
<td>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).</td>
</tr>
<tr>
<td><strong>Brief description exercises</strong></td>
<td>/</td>
</tr>
</tbody>
</table>
| **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 Efficacy  
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
This course teaches students to understand theoretical aspects and techniques of ultrasound-, Magnetic Resonance- and some unconventional imaging systems.

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**

### Lecturer/Institute

Prof. Dössel / IBT

### Credit Points

4,5

### Semester hours

3

### 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 of course

This course teaches students to understand theoretical aspects and techniques of ultrasound-, Magnetic Resonance- and unconventional imaging systems. It provides knowledge of imaging physiological and anatomical information applying non-trivial mathematical methods and modern engineering techniques.

### 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.

### Exercises

- 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
<table>
<thead>
<tr>
<th>Course form</th>
<th>Lecture</th>
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</thead>
<tbody>
<tr>
<td>General remarks</td>
<td>Current information can be found on the ITIV (<a href="http://www.ibt.kit.edu/">http://www.ibt.kit.edu/</a>) webpage and within the eStudium-teachingplatform (<a href="http://www.estudium.org">www.estudium.org</a>).</td>
</tr>
</tbody>
</table>
Course name: Bioelectric Signals

Course code: 23264

Lecturer/Institute: Dr. Seemann / IBT
Credit Points: 3
Semester hours: 2
Term: Sommer term
Bachelor/Master: Bachelor/Master

Prerequisites: Bachelor/Master

Objectives: Bioelectricity and mathematical modelling of the underlying processes

Brief description of 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 on mathematical modelling. This lecture includes a practical with MatLab.

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

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**

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**

- Biopotential Amplifiers: Basic Requirements, Differential Amplifier, Biopotential Pre-Amplifier.
- Biopotentials of Nervsystem and Muscles: Anatomy and Function, Electroneurogram (ENG), Electromyogram (EMG), Nerve Conduction Velocity, Diagnosis, Recording-Technique.

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).
Biomedical Measurement Techniques II

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


The lecturer reserves the right to alter the contents of the course without prior notification.
<table>
<thead>
<tr>
<th>Course name</th>
<th>Laboratory Biomedical Engineering</th>
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<tbody>
<tr>
<td>Course code</td>
<td>23276</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Dössel / IBT</td>
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<tr>
<td>Credit Points</td>
<td>6</td>
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<tr>
<td>Semester hours</td>
<td>4</td>
</tr>
<tr>
<td>Term</td>
<td>Sommer term</td>
</tr>
<tr>
<td>Bachelor/ Master Prerequisites</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Brief description exercises</td>
<td>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.</td>
</tr>
<tr>
<td>Contents</td>
<td>Biomedical signal processing</td>
</tr>
<tr>
<td></td>
<td>Invasive measurement of blood pressure</td>
</tr>
<tr>
<td></td>
<td>Non-invasive measurement of blood pressure</td>
</tr>
<tr>
<td></td>
<td>Electrocardiography</td>
</tr>
<tr>
<td></td>
<td>Amplifier techniques for bioelectric signals</td>
</tr>
<tr>
<td></td>
<td>Impedance measurement in human tissue</td>
</tr>
<tr>
<td></td>
<td>Electrostimulation</td>
</tr>
<tr>
<td></td>
<td>Electromyography and power of muscle contraction</td>
</tr>
<tr>
<td></td>
<td>Haematology</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Material is provided in the internet</td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Oral (see actual document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Laboratory</td>
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<tr>
<td>General remarks</td>
<td>Current information can be found on the IBT (<a href="http://www.ibt.kit.edu/">http://www.ibt.kit.edu/</a>) webpage and within the eStudium-teachingplatform (<a href="http://www.estudium.org">www.estudium.org</a>).</td>
</tr>
<tr>
<td><strong>Course name</strong></td>
<td><strong>Physiology and Anatomy for Engineers I</strong></td>
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<tr>
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<td>------------------------------------------</td>
</tr>
<tr>
<td><strong>Course code</strong></td>
<td><strong>23281</strong></td>
</tr>
<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Dr. Breustedt / INE</td>
</tr>
<tr>
<td><strong>Credit Points</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Semester hours</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Term</strong></td>
<td>Winter term</td>
</tr>
<tr>
<td><strong>Bachelor/ Master</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Elective course</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>Basic Knowledge on the functions of the human body and the processes behind these.</td>
</tr>
<tr>
<td><strong>Brief description course</strong></td>
<td>The course provides basic knowledge of vital physiological systems and gives an insight into medical terminology. The lecture is addressed to all students of technical subjects interested in physiological problems, preferably those who intend to work in medical related fields. The course is continued in the summer term (Course No. 23282).</td>
</tr>
<tr>
<td><strong>Contents</strong></td>
<td>Topics of the first part (winter term)</td>
</tr>
<tr>
<td></td>
<td>Introduction – Organization levels inside the human Body</td>
</tr>
<tr>
<td></td>
<td>Basics of biochemistry in the human body</td>
</tr>
<tr>
<td></td>
<td>Anatomy and Physiology of the Cell, Tissue level</td>
</tr>
<tr>
<td></td>
<td>Internal Transport Mechanisms</td>
</tr>
<tr>
<td></td>
<td>Neurophysiology I (Neuron; Muscle Cell; The Autonomic Nervous System)</td>
</tr>
<tr>
<td></td>
<td>Human Circulatory System with blood and lymph</td>
</tr>
<tr>
<td></td>
<td>Respiratory System</td>
</tr>
<tr>
<td><strong>Lecture notes</strong></td>
<td>Presentation slides (will be provided via the ILIAS system <a href="https://ilias.studium.kit.edu/">https://ilias.studium.kit.edu/</a>), Books will be announced in the course.</td>
</tr>
<tr>
<td><strong>Language</strong></td>
<td>German</td>
</tr>
<tr>
<td><strong>Examination</strong></td>
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</tr>
<tr>
<td><strong>Formation of grade</strong></td>
<td>Grades result from the oral examination</td>
</tr>
<tr>
<td><strong>Course form</strong></td>
<td>Lecture</td>
</tr>
<tr>
<td><strong>General remarks</strong></td>
<td>Recent information can be found on the IBT (<a href="http://www.ibt.kit.edu/">http://www.ibt.kit.edu/</a>) webpage.</td>
</tr>
<tr>
<td>Course name</td>
<td>Physiology and Anatomy for Engineers II</td>
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<tr>
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<tr>
<td>Course code</td>
<td>23282</td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Dr. Breustedt / INE</td>
</tr>
<tr>
<td>Credit Points</td>
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</tr>
<tr>
<td>Semester hours</td>
<td>2</td>
</tr>
<tr>
<td>Term</td>
<td>Sommer term</td>
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<tr>
<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Course 23281</td>
</tr>
<tr>
<td>Objectives</td>
<td>Basic Knowledge on the functions of the human body and the processes behind these.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>This course extends the knowledge acquired from course physiology and Anatomy for Engineers I (No. 23281 in the winter term). The course provides basic knowledge of vital physiological systems and gives an insight into medical terminology. The lecture is addressed to all students of technical subjects interested in physiological problems, preferably those who intend to work in medical related fields.</td>
</tr>
<tr>
<td>Contents</td>
<td>Topics of the second part (summer term)</td>
</tr>
<tr>
<td></td>
<td>· Acid, Base Balance in Man, Water Balance, excretory system</td>
</tr>
<tr>
<td></td>
<td>· Thermoregulation</td>
</tr>
<tr>
<td></td>
<td>· Digestive System and Nutrition</td>
</tr>
<tr>
<td></td>
<td>· Human Endocrine System</td>
</tr>
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<td></td>
<td>· Neurophysiology II (Organization of the Central Nervous System; Motor Control Systems; Sensory Reception and Processing).</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Presentation slides (will be provided via the ILIAS system <a href="https://ilias.studium.kit.edu/">https://ilias.studium.kit.edu/</a>), Books will be announced in the course.</td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Oral (see actual document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture</td>
</tr>
<tr>
<td>General remarks</td>
<td>Recent information can be found on the IBT (<a href="http://www.ibt.kit.edu/">http://www.ibt.kit.edu/</a>) webpage.</td>
</tr>
</tbody>
</table>
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 of 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).
<table>
<thead>
<tr>
<th>Course name</th>
<th><strong>Nuclear Medicine and Measuring Techniques II</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23290</td>
</tr>
<tr>
<td>Lecturer/Institute</td>
<td>Prof. Maul, Prof. Doerfel / IBT</td>
</tr>
<tr>
<td>Credit Points</td>
<td>01. Mai</td>
</tr>
<tr>
<td>Semester hours</td>
<td>1</td>
</tr>
<tr>
<td>Term</td>
<td>Summer term</td>
</tr>
<tr>
<td>Bachelor/Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Objectives</td>
<td>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.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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.</td>
</tr>
</tbody>
</table>
| Contents                   | - Overview of scintigraphic 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. |
| 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**  
*Biokinetics of Radionuclides*

**Course code**  
23294

**Lecturer/ Institute**  
Dr. Bastian Breustedt / INE

**Credit Points**  
3

**Semester hours**  
2

**Term**  
Winter term

**Bachelor/ Master**  
Bachelor/Master

**Elective course**  
Bachelor/Master

**Prerequisites**  
Basic knowledge of radiation protection (e.g. 23271: Radiation Protection I)

**Objectives**  
Biokinetic models and their application in internal dosimetry

**Brief description course**  
The course on „Biokinetics of Radionuclides“ describe the behaviour of radioactive materials after incorporation in the human body. The lectures will mainly cover, besides a short introduction to the physiological bases of biokinetics, the mathematical modelling of the relevant processes in order to assess radiation doses. Focus are the models of the international radiological protection commission, built with the compartmental modelling technique and their application. Examples (e.g. taken from national and international intercomparison exercises) will illustrate the biokinetic modelling and internal dose assessment.

**Contents**  
- Basics of internal dosimetry  
- Intake of radionuclides  
- exposure pathways, intake pathways, conditions  
- Analysis of radionuclides in man (Bioassay)  
- Basics of metabolism  
- Models of metabolism and biokinetics  
- simple and compartmental models  
- reference models of ICRP  
- Assessment of doses after incorporations  
- Analysis of biokinetic (bioassay) data and models  
- Measures for dose reduction after incorporation

**Lecture notes**  
Presentation slides (will be provided via the ILIAS system https://ilias.studium.kit.edu/ ), Books will be announced in the course.

**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**  
Recent information can be found on the IBT (http://www.ibt.kit.edu/) webpage.
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: Summer 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 of 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.

<table>
<thead>
<tr>
<th>Lecture notes</th>
<th>The lecture notes are available online. Assignments will be given out and are available online.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Written (see current document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the written examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>General remarks</td>
<td>The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the webpage of the ETI (<a href="http://www.eti.uni-karlsruhe.de">www.eti.uni-karlsruhe.de</a>).</td>
</tr>
<tr>
<td>Course name</td>
<td>Practical Aspects of Electrical Drives</td>
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<tr>
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<tr>
<td>Course code</td>
<td>23311</td>
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<tr>
<td>Associated Exercise</td>
<td>23313</td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Dr.-Ing. Martin Doppelbauer / ETI</td>
</tr>
<tr>
<td>Credit Points</td>
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<tr>
<td>Semester hours</td>
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<tr>
<td>Term</td>
<td>Summer term</td>
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<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Lecture 23307 – Electrical Machines and Power Electronics</td>
</tr>
<tr>
<td>Objectives</td>
<td>The goal is to relay practical aspects on the field of electrical drives.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>This course is an introduction to electrical drives and electrical drive systems.</td>
</tr>
<tr>
<td>Brief description exercises</td>
<td>Supporting the lecture, assignments to the curriculum are distributed. Their solution is presented and discussed during lecture hall exercises.</td>
</tr>
<tr>
<td>Contents</td>
<td>Lecture</td>
</tr>
<tr>
<td>Drive Systems</td>
<td></td>
</tr>
<tr>
<td>Electric Motors (types, operating principles)</td>
<td></td>
</tr>
<tr>
<td>Mechanical transmission elements (gearboxes, clutches, bearings)</td>
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<tr>
<td>Driven Equipment</td>
<td></td>
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<tr>
<td>Starting procedures and braking</td>
<td></td>
</tr>
<tr>
<td>Thermal protection</td>
<td></td>
</tr>
<tr>
<td>Variable speed drives</td>
<td></td>
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<tr>
<td>Electromagnetic compatibility</td>
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<tr>
<td>Small drives</td>
<td></td>
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<tr>
<td>Noise</td>
<td></td>
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<tr>
<td>Drives with limited movement</td>
<td></td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Online material is available on: <a href="http://www.estudium.org">www.estudium.org</a></td>
</tr>
<tr>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Examination</td>
<td>Written (see actual document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the written examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>General remarks</td>
<td>The course comprises of the interleaved lecture blocks, exercises, and tutorials. Current information can be found on the ETI (<a href="http://www.eti.kit.edu">www.eti.kit.edu</a>) webpage).</td>
</tr>
</tbody>
</table>
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 asynchronous 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 demonstrations 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
<table>
<thead>
<tr>
<th>Examination</th>
<th>Oral (see actual document “Studienplan” and notice of the examination office ETIT).</th>
</tr>
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<tbody>
<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>General remarks</td>
<td>The course comprises of the interleaved lecture blocks and exercises. Current</td>
</tr>
<tr>
<td></td>
<td>information can be found on the webpage of the ETI (<a href="http://www.eti.uni-karlsruhe.de">www.eti.uni-karlsruhe.de</a>).</td>
</tr>
<tr>
<td>Course name</td>
<td><em>Seminar Neue Komponenten und Systeme der Leistungselektronik</em></td>
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<tr>
<td>Course code</td>
<td>23317</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Dr.-Ing. M. Braun / ETI</td>
</tr>
<tr>
<td>Credit Points</td>
<td>4,5</td>
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<tr>
<td>Semester hours</td>
<td>3</td>
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<tr>
<td>Term</td>
<td>Winter term</td>
</tr>
<tr>
<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Objectives</td>
<td>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</td>
</tr>
<tr>
<td>Brief description</td>
<td>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.</td>
</tr>
<tr>
<td>course</td>
<td></td>
</tr>
<tr>
<td>Contents</td>
<td>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:</td>
</tr>
<tr>
<td></td>
<td>- Hybrid drive systems for cars</td>
</tr>
<tr>
<td></td>
<td>- Configuration and characteristics of modern high performance semiconductors</td>
</tr>
<tr>
<td></td>
<td>- Storage of electrical energy</td>
</tr>
<tr>
<td></td>
<td>- Converters in energy transmission systems</td>
</tr>
<tr>
<td></td>
<td>The lecturer reserves the right to alter the contents of the course without prior notification.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>A part of the literature will be presented at the beginning of the course. Literature research by the participants is part of the seminar.</td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Periodic meetings for checking the progress, final presentation</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>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</td>
</tr>
<tr>
<td>Course form</td>
<td>Seminar</td>
</tr>
<tr>
<td>General remarks</td>
<td>Current information can be found on the ETI webpage (<a href="http://www.eti.uni-karlsruhe.de">www.eti.uni-karlsruhe.de</a>).</td>
</tr>
<tr>
<td><strong>Course name</strong></td>
<td>Seminar Leistungselektronik in Systemen der regenerativen Energieerzeugung</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------------------------------------------------------------------</td>
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<tr>
<td><strong>Course code</strong></td>
<td>23318</td>
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<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Prof. Dr.-Ing. M. Braun / ETI</td>
</tr>
<tr>
<td><strong>Credit Points</strong></td>
<td>04. Mai</td>
</tr>
<tr>
<td><strong>Semester hours</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Term</strong></td>
<td>Summer term</td>
</tr>
<tr>
<td><strong>Bachelor/ Master</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Elective course</strong></td>
<td>Bachelor/Master</td>
</tr>
</tbody>
</table>

**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 inquire 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).
<table>
<thead>
<tr>
<th>Course name</th>
<th>High Power Converters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23319</td>
</tr>
<tr>
<td>Associated Exercise</td>
<td>none</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Braun / ETI</td>
</tr>
<tr>
<td>Credit Points</td>
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</tr>
<tr>
<td>Semester hours</td>
<td>2 + 0</td>
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<tr>
<td>Term</td>
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<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Basics of Electrical Engineering, Electrical Machines and Power Electronics</td>
</tr>
<tr>
<td>Objectives</td>
<td>Function and performance of power electronic circuits</td>
</tr>
<tr>
<td>Brief description</td>
<td>Specialized lecture. The main topic is the treatment of mains controlled converters and self-commutated multilevel converters. Further, the application aspects and the protection of power semiconductors are treated.</td>
</tr>
<tr>
<td>exercises</td>
<td>No Exercise</td>
</tr>
<tr>
<td>Contents</td>
<td>Lecture</td>
</tr>
<tr>
<td></td>
<td>The content of the lecture are power electronic circuits. The circuit function is presented and analyzed. Firstly, the basic performance under ideal conditions is given. Secondly, the influence of real conditions is added. Following topics are treated in detail: Mains commutated Power converters: under idealized and 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. Multilevel Converters: Neutral Point Clamped Inverter, Diode Clamped Inverter, Floating Capacitor Inverter, Series Cell Inverter, Modular Multilevel Converter, Hybrid Converters, modulation methods, semiconductors for multilevel converters, applications. 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.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Written lecture material can be downloaded at the ETI website. The password will be announced in the lecture. Proposals for literature are given in the lecture material.</td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Oral (see current document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the examination.</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture</td>
</tr>
<tr>
<td>General remarks</td>
<td>The lecture is considered as first part of the topic Power Electronics.</td>
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</table>
Course name: Power electronics

Course code: 23320

Associated Exercise: none

Lecturer/ Institute: Prof. Braun / ETI
Credit Points: 4.5
Semester hours: 2 + 1
Term: Summer term
Bachelor/ Master: Master
Elective course: Master
Prerequisites: Basics of Electrical Engineering, Electrical Machines and Power Electronics

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.

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 control, 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
The lecture notes are available online. 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 examination.

Course form: Lecture
<table>
<thead>
<tr>
<th>Course name</th>
<th>Hybrid and Electric Vehicles</th>
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<tbody>
<tr>
<td>Course code</td>
<td>23321</td>
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<tr>
<td>Associated Exercise</td>
<td>Yes</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Dr.-Ing. M. Doppelbauer</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3+1,5</td>
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<td>Semester hours</td>
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<td>Bachelor/Master</td>
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<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>None</td>
</tr>
<tr>
<td>Objectives</td>
<td>The goal of the lecture is to provide knowledge about all components that are used in modern electric and hybrid vehicles.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>Starting with the mobility needs of the modern industrialized society and the political goals concerning climate protection, the different drive and charge concepts of battery-electric and hybrid-electric vehicles are introduced and evaluated. The lecture gives a wide overview on all needed components such as electric drive trains, especially batteries, chargers, DC/DC-converters, DC/AC-converters, electrical machines and gear drives.</td>
</tr>
<tr>
<td>Contents</td>
<td>Introduction</td>
</tr>
<tr>
<td></td>
<td>Hybrid concepts</td>
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<tr>
<td></td>
<td>Driving performance and energy consumption</td>
</tr>
<tr>
<td></td>
<td>Drive train</td>
</tr>
<tr>
<td></td>
<td>Control strategy</td>
</tr>
<tr>
<td></td>
<td>Energy storage</td>
</tr>
<tr>
<td></td>
<td>Asynchronous motor</td>
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<tr>
<td></td>
<td>Synchronous motor</td>
</tr>
<tr>
<td></td>
<td>Special machines</td>
</tr>
<tr>
<td></td>
<td>Power electronics</td>
</tr>
<tr>
<td></td>
<td>charging</td>
</tr>
<tr>
<td></td>
<td>Enviroment</td>
</tr>
<tr>
<td></td>
<td>Vehicle examples</td>
</tr>
<tr>
<td></td>
<td>The lecturer reserves the right to alter the contents of the course without prior notification.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Slides</td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Oral (20 min.)</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grade of the oral examination</td>
</tr>
<tr>
<td>Course form</td>
<td>15 double periods of lectures, 8 double periods of exercises</td>
</tr>
</tbody>
</table>
Course name: Design of electrical machines

Course code: 23324

Associated Exercise: Yes

Lecturer/Institute: Prof. Dr.-Ing. M. Doppelbauer

Credit Points: 3+1.5

Semester hours: 2+1

Term: Winter term

Bachelor/Master: Bachelor/Master

Elective course: Bachelor/Master

Prerequisites: Module „Electrical Machines and Power Electronics“

Objectives: The goal is to provide the knowledge for designing electrical machines

Brief description of course: The lecture provides the basics of the calculation and design of electrical machines. The focus is especially on the generation of the rotary field and forces, on different windings and on the magnetic circuit. The students are taught to design electrical machines for specific purposes from scratch.

Contents:
- Introduction
- Windings
- Magnetic circuit
- Numerical field calculation
- System equations of rotary field machines
- Operation of rotary field machines
- (Stray) Inductances and skin effect
- Losses
- Forces and torque
- Magnetic noise
- Design and calculation procedure
- The lecturer reserves the right to alter the contents of the course without prior notification.

Lecture notes: Slides

Language: German

Examination: Exam (2h)

Formation of grade: Grade of the exam

Course form: 15 double periods of lectures, 8 double periods of exercises
Course name: Circuit Design in Industrial Electronics

Course code: 23327

Lecturer/Institute: Liske, Andreas
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: The lecturer 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.
<table>
<thead>
<tr>
<th>Course name</th>
<th>converter control technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23330</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Liske, Andreas</td>
</tr>
<tr>
<td>Credit Points</td>
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<tr>
<td>Semester hours</td>
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<tr>
<td>Term</td>
<td>Summer term</td>
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<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Lecture 23307 - Electrical Machines and Power Electronics</td>
</tr>
<tr>
<td>Objectives</td>
<td>Knowledge about analogue and digital principles for controlling converters</td>
</tr>
<tr>
<td>Brief description course</td>
<td>The lecture presents several controllers for converters. The theoretical aspects are described as well as the practical implementation is described.</td>
</tr>
<tr>
<td>Contents</td>
<td>Lecture</td>
</tr>
<tr>
<td></td>
<td>fundamental terms of electromagnetism</td>
</tr>
<tr>
<td></td>
<td>mmf, flux and flux linkage</td>
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<tr>
<td></td>
<td>law of induction</td>
</tr>
<tr>
<td></td>
<td>system equations</td>
</tr>
<tr>
<td></td>
<td>equivalent circuit</td>
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<td></td>
<td>calculation of inductance</td>
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<td>main- and leakage flux</td>
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<tr>
<td></td>
<td>main- and leakage inductance</td>
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<td>Rogowski-factor</td>
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<td>steady-state operation</td>
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<td>load characteristic</td>
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<tr>
<td></td>
<td>efficiency</td>
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<td></td>
<td>dynamic response</td>
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<td></td>
<td>inrush</td>
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<td></td>
<td>short circuit</td>
</tr>
<tr>
<td></td>
<td>force</td>
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<td>The lecturer reserves the right to alter the contents of the course without prior notification.</td>
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<tr>
<td>Language</td>
<td>German</td>
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<tr>
<td>Examination</td>
<td>Oral (see current document “Studienplan” and notice of the examination office ETIT).</td>
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<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
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<tr>
<td>Course form</td>
<td>Lecture</td>
</tr>
<tr>
<td>General remarks</td>
<td>Current information can be found on the ETI (<a href="http://www.eti.kit.edu">www.eti.kit.edu</a>) webpage.</td>
</tr>
<tr>
<td>Course name</td>
<td>Laboratory Electrical Drives and Power Electronics</td>
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<tr>
<td>Course code</td>
<td>23331</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr.-Ing. K.-P. Becker / ETI</td>
</tr>
<tr>
<td>Credit Points</td>
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<td>Semester hours</td>
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<tr>
<td>Term</td>
<td>Summer term</td>
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</tr>
<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Lecture: Leistungselektronik, Regelung elektrischer Antriebe recommended: Energietechnisches Praktikum</td>
</tr>
<tr>
<td>Objectives</td>
<td>The goal is the practical use of modern drives and power electronics.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>Laboratory for advanced students with the focus on electrical drives and power converter technology.</td>
</tr>
<tr>
<td>Contents Laboratory</td>
<td>The laboratory leads to practical knowledge on applications with electrical drives and power electronics in the following 8 experiments:</td>
</tr>
<tr>
<td></td>
<td>Field orientated control of induction machines</td>
</tr>
<tr>
<td></td>
<td>Permanent magnet synchronous machine</td>
</tr>
<tr>
<td></td>
<td>Space vector transformation and current control with the digital signal processor</td>
</tr>
<tr>
<td></td>
<td>Power semiconductor</td>
</tr>
<tr>
<td></td>
<td>Speed-controlled dc-machine drive in four-quadrant operation</td>
</tr>
<tr>
<td></td>
<td>line commutated converter</td>
</tr>
<tr>
<td></td>
<td>circle diagram of the induction machine</td>
</tr>
<tr>
<td></td>
<td>Synchronous generator (cylindrical rotor)</td>
</tr>
<tr>
<td></td>
<td>The lecturer reserves the right to alter the contents of the course without prior notification.</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>Material for this laboratory is send to the participants by email</td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
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<tr>
<td>Examination</td>
<td>An oral examination will take place for every experiment (see current document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>The final grades result from the arithmetic mean of the 8 grades from every experiment.</td>
</tr>
<tr>
<td>Course form</td>
<td>Laboratory</td>
</tr>
<tr>
<td>General remarks</td>
<td>Current information can be found on the ETI webpage (<a href="http://www.eti.kit.edu">www.eti.kit.edu</a>).</td>
</tr>
<tr>
<td><strong>Course name</strong></td>
<td>Workshop „Circuit Design in Power Electronics“</td>
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<td>----------------</td>
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<td><strong>Course code</strong></td>
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<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Becker / ETI</td>
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<tr>
<td><strong>Credit Points</strong></td>
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<td><strong>Term</strong></td>
<td>Summer term</td>
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<td>Bachelor/Master</td>
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<td><strong>Elective course</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Prerequisites</strong></td>
<td>Module „Electrical Machines and Power Electronics“</td>
</tr>
</tbody>
</table>

**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“ is available online

**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.
<table>
<thead>
<tr>
<th><strong>Course name</strong></th>
<th>System Analysis and Dynamic Operation of Three-Phase-Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Course code</strong></td>
<td>23344</td>
</tr>
<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Dr. Becker / ETI</td>
</tr>
<tr>
<td><strong>Credit Points</strong></td>
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</tr>
<tr>
<td><strong>Semester hours</strong></td>
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<td><strong>Term</strong></td>
<td>Summer term</td>
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<tr>
<td><strong>Bachelor/ Master</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Elective course</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Prerequisites</strong></td>
<td>Basic study knowledge of mathematics</td>
</tr>
</tbody>
</table>

**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-inductances and mutual inductances 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 and highly dynamic drives.

**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.


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. Photographs of blackboard notes on homepage. Supplementary sheets are distributed during lectures and available on homepage. Math-Cad examples (on institute computers available).


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.
<table>
<thead>
<tr>
<th><strong>Course name</strong></th>
<th>Workshop „Microcontrollers in Power Electronics“</th>
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</thead>
<tbody>
<tr>
<td><strong>Course code</strong></td>
<td>23345</td>
</tr>
<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Liske / ETI</td>
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<tr>
<td><strong>Credit Points</strong></td>
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</tr>
<tr>
<td><strong>Semester hours</strong></td>
<td>2</td>
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<tr>
<td><strong>Bachelor/ Master</strong></td>
<td>Bachelor/Master</td>
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<tr>
<td><strong>Elective course</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Prerequisites</strong></td>
<td>Module „Electrical Machines and Power Electronics“, Basics of the programming language C</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>Objective is the ability of programming microcontrollers.</td>
</tr>
<tr>
<td><strong>Brief description course</strong></td>
<td>The students learn about the characteristics of programming a microcontroller. They are supplied with a microcontroller controlled buck-boost-inverter set-up, a workplace with a computer and hardware for programming the microcontroller. At the end of the workshop, they should have written a program for the microcontroller to drive the dc-dc-converter for a regulated output voltage.</td>
</tr>
<tr>
<td><strong>Contents</strong></td>
<td>In this workshop, the students are supplied with a buck-boost converter with microcontroller control. Until the end of the module they have to program the microcontroller to regulate the dc-dc-converter output voltage. The special attributes of the C programming language for microcontrollers are presented during the workshop. The most important topics are - ability for real time computation - limited computing power - defined precision for calculations - registers for configuring the internal special hardware Information about the converter hardware and the requested software functions are provided. Workplaces and necessary programming hardware are assigned to the students. They learn to program the microcontroller with assistance of tutors during the workshop afternoons. They make the following steps autonomously: - programming of a sequential control algorithm - configuring of the value measurement - programming of the PWM modulator - programming of a cascaded control for constant output voltage The individual 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.</td>
</tr>
<tr>
<td><strong>Lecture notes</strong></td>
<td>Materials are provided on the workshop afternoons</td>
</tr>
<tr>
<td><strong>Language</strong></td>
<td>German</td>
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<tr>
<td><strong>Examination</strong></td>
<td>Demonstration of the operation of the microcontroller program. Writing a short abstract about the approach during the workshop (approx. 5 – 10 pages) Oral examination (approx. 10 minutes per participant)</td>
</tr>
<tr>
<td><strong>Formation of grade</strong></td>
<td>The grade is deduced by the fulfillment of the required software specifications, the abstract and the oral examination.</td>
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<tr>
<td><strong>Course form</strong></td>
<td>7 afternoons.</td>
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<tr>
<td><strong>General remarks</strong></td>
<td>The number of participants is limited since every student needs an individual workplace.</td>
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<td>Course name</td>
<td>Power Electronics for Regenerative Energy Sources</td>
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<td>---------------------------------</td>
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<td>Course code</td>
<td>23347</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Dr.-Ing. Burger / ETI</td>
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<td>Credit Points</td>
<td>3</td>
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<td>Semester hours</td>
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<td>Term</td>
<td>Winter term</td>
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<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
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<tr>
<td>Elective course</td>
<td>Module Power Electronics</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Module Power Electronics</td>
</tr>
<tr>
<td>Objectives</td>
<td>The goal is to get a survey of the different possibilities of generating energy from regenerative sources. The students should attain special knowledge about photovoltaics and power electronics for solar cells.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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.</td>
</tr>
</tbody>
</table>
| 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 resources
- 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
<table>
<thead>
<tr>
<th>Course name</th>
<th><strong>High-Voltage Technology I</strong></th>
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<tbody>
<tr>
<td>Course code</td>
<td>23360</td>
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<tr>
<td>Associated Exercise</td>
<td>23362</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr.-Ing. Rainer Badent/IEH</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3+1,5</td>
</tr>
<tr>
<td>Semester hours</td>
<td>2+1</td>
</tr>
<tr>
<td>Term</td>
<td>Summer term</td>
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<tr>
<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
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<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Basic Network and Field Theory</td>
</tr>
<tr>
<td>Objectives</td>
<td>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.</td>
</tr>
<tr>
<td>Brief description</td>
<td>Electrical Fields, Dielectrics</td>
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<tr>
<td>course</td>
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<tr>
<td>Contents</td>
<td>Electric potential fields</td>
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<tr>
<td></td>
<td>Maxwell's equations</td>
</tr>
<tr>
<td></td>
<td>Calculation of static electric fields, charge simulation method</td>
</tr>
<tr>
<td></td>
<td>Difference method, Finite-Element method, Monte-Carlo method, Boundary-element method</td>
</tr>
<tr>
<td></td>
<td>Graphical field evaluation</td>
</tr>
<tr>
<td></td>
<td>Measurement of electric fields, field energy and field forces</td>
</tr>
<tr>
<td></td>
<td>Polarization, boundary layers, inclusions, DC and AC voltage distribution in dielectrics</td>
</tr>
<tr>
<td></td>
<td>Frequency and temperature dependency of the dissipation factor</td>
</tr>
<tr>
<td></td>
<td>Generation of high DC/AC and impulse voltages and high impulse currents for testing</td>
</tr>
<tr>
<td></td>
<td>The lecturer reserves the right to alter the contents of the course without prior notification.</td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Written</td>
</tr>
</tbody>
</table>
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: 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: Dielectrics Insulation Coordination

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, transmission 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
**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** This lecture deals with the calculation of the power grid. This comprises the calculation of load flows in the steady-state operation of the grid and is added by short circuit current calculations. Short circuit current calculations are split into 3 phase symmetrical short circuits and asymmetrical faults in the grid. Finally, the lecture deals with the basics of High-Voltage technology.

**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 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 second 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 third 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 fourth 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.

In its last 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.

**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 basics of power transmission in the medium and high-voltage grid. 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 into 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 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).
Electronic Systems and EMC

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
<table>
<thead>
<tr>
<th>Course name</th>
<th><strong>Photovoltaic system technology</strong></th>
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</thead>
<tbody>
<tr>
<td>Course code</td>
<td><strong>23380</strong></td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr. Heribert Schmidt / IEH</td>
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<tr>
<td>Credit Points</td>
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<td>Semester hours</td>
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</tr>
<tr>
<td>Term</td>
<td>Summer term</td>
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<tr>
<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
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<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
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<tr>
<td>Prerequisites</td>
<td>none</td>
</tr>
<tr>
<td>Objectives</td>
<td>The goal is to relay theoretical fundamentals.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>The fundamentals of photovoltaic systems technology will be presented.</td>
</tr>
<tr>
<td>Contents</td>
<td>Lecture</td>
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<td>Ways of solar energy utilisation</td>
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<td>The terrestrial solar radiation</td>
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<td>Solar radiation measuring principles</td>
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<td>Fundamentals of solar cells</td>
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<td>Overview of typical cell technologies</td>
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<td>Efficiency values</td>
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<td>Equivalent circuit diagram of solar cells</td>
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<td>Properties of solar cells and solar modules</td>
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<td>Series and parallel connection of solar cells</td>
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<td>Matching of solar generators and loads</td>
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<td>MPP-Tracking</td>
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<td>Construction of PV-modules</td>
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<tr>
<td>Partial shading, bypass-technologies</td>
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<tr>
<td>Overview of different System configurations</td>
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<td>Batteries for PV applications</td>
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<td>Charge controllers</td>
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<td>Battery peripherals</td>
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<td>Inverters for stand-alone systems</td>
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<td>Inverters for grid connected systems</td>
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<td>European efficiency</td>
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<tr>
<td>Safety and EMC aspects</td>
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<tr>
<td>Annual yield of PV systems</td>
<td></td>
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<tr>
<td>Economic evaluation of PV systems</td>
<td></td>
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<tr>
<td>Examples of realised PV systems</td>
<td></td>
</tr>
<tr>
<td>The lecturer reserves the right to alter the contents of the course without prior notification.</td>
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</tr>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Written (see actual document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the written examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture</td>
</tr>
<tr>
<td>General remarks</td>
<td>The lecturer is member of the Fraunhofer Institute for Solar Energy Systems ISE, Freiburg.</td>
</tr>
</tbody>
</table>
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
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
<table>
<thead>
<tr>
<th>Course name</th>
<th>Energy Economics</th>
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</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23383</td>
</tr>
<tr>
<td>Associated Exercise</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Gerhard Weissmueller, Prof. Dr. Eng. / IEH</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3</td>
</tr>
<tr>
<td>Semester hours</td>
<td>2</td>
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<tr>
<td>Term</td>
<td>Winter term</td>
</tr>
<tr>
<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>none</td>
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</tbody>
</table>

**Objectives**

The goal is to convey 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.

**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 for 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.

<p>| 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) |</p>
<table>
<thead>
<tr>
<th><strong>Course name</strong></th>
<th><strong>Business Management for Engineers based on Case Studies</strong></th>
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<tbody>
<tr>
<td><strong>Course code</strong></td>
<td>23387</td>
</tr>
<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Prof. Dr. Schröppel/IEH</td>
</tr>
<tr>
<td><strong>Credit Points</strong></td>
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<tr>
<td><strong>Semester hours</strong></td>
<td>2</td>
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<tr>
<td><strong>Term</strong></td>
<td>Winter term</td>
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<tr>
<td><strong>Bachelor/ Master</strong></td>
<td>Bachelor/Master</td>
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<tr>
<td><strong>Elective course</strong></td>
<td>Key Qualification</td>
</tr>
<tr>
<td><strong>Prerequisites</strong></td>
<td>none</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>The goal is to impart practical business management knowledge</td>
</tr>
<tr>
<td><strong>Brief description course</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Contents</strong></td>
<td>Lecture</td>
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<td></td>
<td>1. Introduction</td>
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<td>2. Business plan</td>
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<td>3. Budgeting and forward planning</td>
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<td>4. Cost structures for personnel work</td>
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<td></td>
<td>5. Prices for products and services</td>
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<td></td>
<td>6. Management of projects</td>
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<td></td>
<td>7. Calculation of return on investment</td>
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<td>8. Evaluation of the value of a company</td>
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<td></td>
<td>9. Balance sheet, profit and loss account, cash flow calculation</td>
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<tr>
<td></td>
<td>The lecturer reserves the right to alter the contents of the course without prior notification.</td>
</tr>
<tr>
<td><strong>Lecture notes</strong></td>
<td>The lecture notes are distributed during the courses. No further literature needed.</td>
</tr>
<tr>
<td><strong>Language</strong></td>
<td>German</td>
</tr>
<tr>
<td><strong>Examination</strong></td>
<td>Written</td>
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<tr>
<td><strong>Formation of grade</strong></td>
<td>The grades result from the written examination</td>
</tr>
<tr>
<td><strong>Course form</strong></td>
<td>Lecture</td>
</tr>
<tr>
<td><strong>General remarks</strong></td>
<td>none</td>
</tr>
</tbody>
</table>
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 lecture 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
<table>
<thead>
<tr>
<th>Examination</th>
<th>Oral (see actual document “Studienplan” and notice of the examination office ETIT).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture</td>
</tr>
<tr>
<td>General remarks</td>
<td>The course consists of seven lecture blocks and one factory visit. Date and time is announced on the blackboards.</td>
</tr>
</tbody>
</table>
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).
<table>
<thead>
<tr>
<th>Course name</th>
<th>High-Voltage Test Technique</th>
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<tbody>
<tr>
<td>Course code</td>
<td>23392</td>
</tr>
<tr>
<td>Associated Exercise</td>
<td>23394</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr.-Ing. Rainer Badent</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3+1.5</td>
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<tr>
<td>Semester hours</td>
<td>2+1</td>
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<td>Term</td>
<td>Winter term</td>
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<td>Elective course</td>
<td>Bachelor/Master</td>
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<tr>
<td>Prerequisites</td>
<td>High-Voltage-Technology I and II</td>
</tr>
</tbody>
</table>

**Objectives**
This course familiarizes the students with issues of high voltage testing, calibration and the contents of the international test standards of products for energy transmission and distribution.

**Brief description course**
This course familiarizes the students with issues of high voltage testing, calibration and the contents of the international test standards of products for energy transmission and distribution.

**Brief description exercises**
Lightning Impulse Test PD-Measurement

**Contents**
- Standards of High voltage test technique
- On-Site testing
- PD-measurement
- Cable and accessories
- Switchyard
- Insulators and transmission line fittings
- Computer aided test systems for 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
<table>
<thead>
<tr>
<th>Course name</th>
<th>Automation of Power Grids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23396</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr.-Ing. Roland Eichler / Siemens AG</td>
</tr>
<tr>
<td>Credit Points</td>
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<td>Semester hours</td>
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</tr>
<tr>
<td>Term</td>
<td>Summer term</td>
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<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Basic knowledge of power transmission and distribution; basic knowledge of IT</td>
</tr>
<tr>
<td>Objectives</td>
<td>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</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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 man-machine interface are treated among others with the help of a</td>
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<tr>
<td>Lecture notes</td>
<td>Slides of the lecture presentation</td>
</tr>
<tr>
<td>Language</td>
<td>German</td>
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<tr>
<td>Examination</td>
<td>Oral (see actual document “Studienplan” and notice of the examination office ETIT)</td>
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<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
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<tr>
<td>Course form</td>
<td>Lecture</td>
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</tbody>
</table>
**Course name**
Laboratory Electrical Power Engineering

**Course code**
23398

**Lecturer/ Institute**
Dr.-Ing. R. Badent / IEH, 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 IEH homepage (www.kit.edu), as well as 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 and technologies behind, like Phased Array. 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 CW-Radar, FM-CW-Radar, Pulse Radar and to advanced Radar system 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), RCS-measurement techniques and Radar 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. The most promising system concepts are Digital Beam Forming (DBF), coding of the Radar signals f.e OFDM, MIMO-Radar and MIMO Array Imaging, they will be the main stream in this part. Compared to conventional Radar systems, the advantages and disadvantages are addressed. The resulting advanced system concepts are applicable to most Radar types, like automotive Radar or High Resolution Wide Swath (HRWS) SAR system. The lecture provides not only the technical description for these new 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.

Lecture notes
Online material is available on: http://www.ihe.uni-karlsruhe.de/805.php

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
General 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.

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: Mikrowellentechnik / Microwave Engineering

Course code: 23407

Associated Exercise: 23409

Lecturer/ Institute: Prof. Zwick & Dr. Pauli / IHE

Credit Points: 4,5 + 1.5

Semester hours: 3 + 1

Term: Winter term & summer 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 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 microwave components starting from waveguides to filters, resonators, power dividers, couplers as well as directional lines and circulators.

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 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.

Lecture notes

Information to the lecture can be found online at www.ihe.kit.edu. Documents for the lecture and the exercise can be downloaded via ILIAS by the students.

Language

German (WS) & English (SS)

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). Documents for the lecture and the exercise can be downloaded via ILIAS by the students.
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: field theory, principles of all important antenna structures, antenna measurement techniques, as well as an insight into modern antenna systems.

Brief description exercises: Hands-on exercise with computer-aided design and simulation of antennas, fabrication and measurement. Additional exercises in the lecture hall and programming tutorial about antenna arrays.

Contents: Lecture

This lecture concerning antennas and antenna systems is a specialisation in the area of microwave 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 communication provide an optimum combination of theory and practical application.

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 Hertz’ian 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 these radiators the main representatives of this category, the horn antenna, patch 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.

Increasing demand for broadband antennas in recent times lead to a fast development. Thus, this lecture treats the different concepts for frequency independent or ultra wideband antennas in detail.

Antenna measurements are a very special topic in microwave measurement techniques. In a separate chapter the state-of-the art measurement techniques for the gain and the radiation pattern of an antenna are described.
In the last part of the lecture, a broad range of antenna systems are introduced and their configuration as well as their functionality is 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. Extensive examples of modern antenna systems are given as a demonstration of this chapter.

Exercises

The exercise is a hands-on training of the lectures theory. It takes place according to a schedule in different training locations, which is a workstation pool in the SCC, lab rooms at IHE and the lecture hall.

In the first part of the exercise, antennas are designed, implemented and measured. After an introduction to CST Microwave Studio, the theoretical background of the solvers, the control and implications of meshing and the modeller, the students start designing their own antennas. These antennas are built in one of IHE’s lab rooms and their gain and radiation pattern is measured in the anechoic chamber.

Fundamentals of antenna engineering are applied to typical problems in an exercise in the lecture hall.

In the last part of the exercise, the properties of antenna arrays are computed in a programming course using MATLAB. The effects of the number, distance and pattern of the array elements and the phase and amplitude of the excitation are visualized. No prior knowledge of MATLAB is required for this part.

The e-learning system ILIAS is used for distribution of lecture and exercise materials, grouping of students, support via a discussion forum and organizational announcements.

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

Lecture notes

Material to the lecture and the link to the ILIAS system 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. 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,
Credit Points: 3 + 1,5
Semester hours: 2 + 1
Term: Bachelor/Master
Bachelor/ Master: Bachelor/Master
Elective course: Bachelor/Master
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.
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<table>
<thead>
<tr>
<th>Lecture notes</th>
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<tbody>
<tr>
<td>Language</td>
<td>English</td>
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<tr>
<td>Examination</td>
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</tr>
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<td>Formation of grade</td>
<td>Grades result from the written examination</td>
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<td>Course form</td>
<td>Lecture, Exercises</td>
</tr>
<tr>
<td>General remarks</td>
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</tbody>
</table>
### Course name

**Microwave Laboratory II**

### Course code

**23415**

### Lecturer/ Institute

Dr.-Ing. Pauli 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 of 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.

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

Lecture notes
Information to the lecture can be found online at www.ihe.kit.edu, the material for the exercises are available via the ILIAS system.

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 (20%), the journal (40%) and the written or oral exam (40%). The final grade is the arithmetic mean of all eight experiments. Students failing the exam are not allowed to take part in the corresponding experiment. The experiment has to be repeated at a different date.

Course form
Laboratory in groups of 2-4 students

General remarks
General advise can be found at www.ihe.kit.edu
Semiconductor Circuits for microwave and millimeter-wave application

Course name:  

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: Dr.-Ing. Pauli / IHE

Credit Points: 04. Mai

Semester hours: 2 + 1

Term: Summer term

Bachelor/Master: 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-, sweep generators 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.

Lecture notes


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. Lecture notes can be found in the ILIAS system.
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<thead>
<tr>
<th>Course name</th>
<th>Microwave Laboratory I</th>
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<tbody>
<tr>
<td>Course code</td>
<td>23423</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr.-Ing. Pauli and academic staff / IHE</td>
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<tr>
<td>Credit Points</td>
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<td>Semester hours</td>
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<td>Term</td>
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<tr>
<td>Prerequisites</td>
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</table>

**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 students four different experiments are accomplished and journalised during eight afternoons. The order and topics of the experiments may vary.

**Contents**
Laboratory:

1. **Design of Millimeter-Wave Integrated Circuit Components with Agilent ADS**
   Abstract: In this exercise of the laboratory, integrated passive (planar filter, hybrid coupler) and active (balanced amplifier) components for millimeter-wave frequency range (30 to 300 GHz) applications are designed.

2. **Wave propagation and network planning**
   Abstract: In this course a hands-on introduction to radio channel description, modeling and cellular network planning is given.

3. **Microwave and RF Measurements: Characterization of a Microwave Transceiver**
   Abstract: The aim of this course is to understand the functionality of microwave measurement equipment such as signal generators, spectrum analyzers and vector network analyzers, as well as to learn the handling of this equipment. During the two exercises these microwave measurement instruments are used to characterize microwave devices such as amplifiers, mixers, filters, oscillators and a full transceiver circuit.

4. **Microwave FMCW Radar**
   Abstract: In this experiment, you are able to familiarize with a 24 GHz Frequency Modulated Continuous Wave (FMCW) Radar, which is nowadays widely applied in civil applications (Automotive radar, radar altimeter and etc.) and military applications (air surveillance, landmines detection and etc.). During this experiment the performance of this type of radar, regarding range detection, range resolution, velocity detection are investigated.

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

**Lecture notes**
Information to the lecture can be found online at www.ihe.kit.edu, the materials to the exercises are available via the ILIAS system.

**Language**
English
<table>
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<th>Examination</th>
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</tr>
<tr>
<td>Course form</td>
<td>Laboratory in groups of 2 students each</td>
</tr>
<tr>
<td>General remarks</td>
<td>General advise can be found at <a href="http://www.ihe.kit.edu">www.ihe.kit.edu</a></td>
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</table>
Course name: Spaceborne SAR Remote Sensing

Course code: 23424

Associated Exercise: 23426

Lecturer/Institute: Prof. Moreira (German Aerospace Center, DLR) / IHE

Credit Points: 3 + 1.5

Semester hours: 2 + 1

Term: Summer term

Bachelor/Master: Bachelor/Master

Prerequisites: Signal processing radar fundamentals.

Objectives: Fundamentals, theory and applications of spaceborne radar systems

Brief description course: The lecture is interdisciplinary and well suited for 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 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. We have 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. Further dedicated topics are explained to deepen the understanding of the main lecture contents.

Contents: The 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 closely related to current projects and research activities being performed at the Microwaves and Radar Institute of the German Aerospace Center (DLR, for more information please see www.dlr.de/HR).

Lecture notes: Material to the lecture can be found online at www.ihe.kit.edu/VorlesungenSS_892.php or ftp://sar-lectures@www.microwaves-and-radar.dlr.de (Password required)

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).
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
Optional 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
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
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: 4
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 of 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: System in a Package (SiP) for millimeter wave applications

Course code: 23433

Associated Exercise: ---

Lecturer/Institute: Dr.-Ing. Pauli / IHE

Credit Points: 3

Semester hours: 2

Term: Winter term

Bachelor/Master: Bachelor/Master

Elective course: Bachelor/Master

Prerequisites: Basic knowledge of higher mathematics, of fields and waves and of electric circuits, fundamentals of microwave engineering

Objectives: The lecture covers theoretical basics of microwave electronics packaging technologies and interconnections.

Brief description course: Specialisation lecture about microwave engineering: the main topics of the lecture are to give a basic knowledge of chip-level connections (wire-bond, TAB, Flip-Chip, etc.) and the requirements on packaging techniques and materials with respect to high frequency capability, power supply and thermal constraints. The lecture gives an overview of state-of-the-art processes in the industry.

Brief description exercises: ---

Contents: Lecture

First, there is a brief introduction to the growing demands in packaging technologies and hence the resulting developments. Due to decreasing dimensions of IC size and simultaneous increasing of I/O count, the first topic gives an outline of the developments in package-to-board connections. Afterwards the technologies of chip-to-package connections (wirebond, TAB, flip chip) are presented. General aspects in package design are introduced, however, electrical (signal- and power lines) and thermal (e.g. heat transfer) properties are focused. To serve the desires of increasing packaging densities, conventional technologies are not usable anymore. By merging technologies from Level 1.0 and Level 2.0 connections, the manufacturing of multi-chip and multi-layer methods are presented. Different methods like thick film, thin film and cofired ceramic processes are treated. In case of millimeter wave interconnects low-loss waveguide connects are used in addition to standard planar lines and are also treated within this lecture. The performance of the system is also depending on the quality of the substrate material and the casting compound.

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

Lecture notes: Material for the lecture can be found online via the ILIAS System 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

General remarks: One practical lecture will be held in the millimetre wave laboratory and it is planned to have an external lecturer from the industry. Current information is available on the webpage of the IHE (www.ihe.kit.edu).
Course name: **High Power Microwave Technologies**

Course code: **23435**

Associated Exercise: ---

Lecturer/Institute: Prof. John Jelonnek / IHE

Credit Points: 3

Semester hours: 2

Term: Winter term

Bachelor/Master: Bachelor/Master

Elective course: Bachelor/Master

Prerequisites: none

Objectives: Fundamentals of high power microwave technology using vacuum tubes, technologies for microwave tubes and -components, RF transmission and diagnostics at high power levels, applications in UHF transmission, satellite communications, radar applications, THz-spectroscopy, material processing with microwaves and fusion applications.

Brief description course: High power microwave technology includes the generation, transmission, application and diagnostics of microwaves at high and highest power levels. The frequency ranges from below 1 GHz (wavelengths of above 30 cm) to 1 THz (wavelengths of below 1 mm). The considered RF power ranges from 1 W (at THz frequencies) to above 1 MW in the classic microwave area (1 GHz to 300 GHz). The lecture focuses on vacuum tubes as RF power generators and amplifiers as those devices are the only ones which span the named frequency and power ranges. It fulfills the need for modern satellite communications, THz-spectroscopy, radar technologies, particle accelerators and fusion applications which have a strongly increasing demand in more and more efficient systems for high power microwave generation and transmission.

The lecture has a strong interdisciplinary character. Obviously, technologies for vacuum tubes and components are dominating. For every discussed type of vacuum tube the corresponding focus applications are presented. Components for high power RF transmission and diagnostics are discussed.

Brief description exercises: no

Contents: The focal points of the lecture are:

- Introduction into high power microwave technologies
- Dominant vacuum tubes and their modern applications as UHF-amplifiers, for satellite communication, radar applications, THz-spectroscopy, particle accelerators and fusion experiments
- Components technologies for vacuum tubes
- Mode converters, quasi-optical launchers and power transmission
- RF-diagnostics for high power microwaves

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:

- J. Eichmeier, M. Thumm “Vacuumelectronics”
- A. S. Gilmour, Jr. “Klystrons, Travelling Wave Tubes, Magnetrons, Crossed-Field Amplifiers and Gyrotrons”

Language: German
<table>
<thead>
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<td>Actual information can be found at the internet page of the IHE (<a href="http://www.ihe.kit.edu">www.ihe.kit.edu</a>).</td>
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</table>
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: 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.

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 of the 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, fundamentals of quantum theory, biological action of electromagnetic waves and hazards, radiation and exposure limits and

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

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Material to the lecture can be found online at www.ihe.kit.edu.

Language: German
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<td>Current information can be found at the internet page of the IHE (<a href="http://www.ihe.kit.edu">www.ihe.kit.edu</a>).</td>
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</table>
## Course name

**Management Systems for Communication Networks**

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### Course code

**23446**

### Lecturer/Institute

Dr.-Ing. Jens Haala, Dr. rer. nat. Peter Troche / IHE

### Credit Points

3

### Semester hours

2

### Term

Summer term

### Bachelor/Master

Bachelor/Master

### Elective course

Bachelor/Master

### Prerequisites

Knowledge in network technologies. However, if required by the audience the basics will be presented during the lecture.

### Objectives

At the end of the lecture students should know the basic principals of the management of communication networks. They should know the different management disciplines and the different forms of standardization in network management. Furthermore students should also get knowledge about the transport of management information and they should be aware of the principle management structures.

### Brief description of course

This lecture is about the architecture of future oriented network management systems and their underlying technologies. Building on the basic concepts of standardized management architectures (OSI management, TMF), the concepts of system-wide and vendor-independent management of resources and services of networked communication systems are presented.

### Contents

#### Lecture

The progressive liberalization of the global communications market will result in a host of new operators, new services and technologies (e.g. Ethernet, ATM, GPRS, UMTS). The network operators are in a strong competitive environment marked by many challenges: The growing demand for transmission capacity and the increasing demands on the offered services, price and quality of service require new concepts of network management.

An advanced management system must not be limited to the configuration and fault management of the network elements, but must manage the entire end-to-end transmission paths of a compound including the services with their customers. It must be flexible and adaptable to the needs of the network operator and integrated into business processes

#### Topics covered:

- Definition of network management, ITU-T Recommendations, M.3xxx Series
- Access networks / transport networks: Physical and Logical Structures
- Requirements of a modern network management system: multi-technology, multi-service, multi-vendor
- NMS architectures
- The TMN pyramid: element layer, network layer, service layer, business layer
- The OSI model
- The DCN (Data Communication Network)
- Network management protocols: Q3, Q3p, Qd2, SNMP
- Management functions: fault, configuration, performance management, topology and inventory, workflow management, trouble tickets
- Service management, path-related quality monitoring
- Integrated power management
- Network management interfaces, CORBA, and cross-domain management
- NGOSS standard of the Tele Management Forum
<table>
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<th>Lecture notes</th>
<th>Online material is available on: <a href="http://www.ihe.kit.edu/VorlesungenSS_netm.php">http://www.ihe.kit.edu/VorlesungenSS_netm.php</a></th>
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<td>Current information about dates and the download of the script can be found here: <a href="http://www.ihe.kit.edu/VorlesungenSS_netm.php">http://www.ihe.kit.edu/VorlesungenSS_netm.php</a></td>
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<tr>
<td>Course name</td>
<td><strong>Advanced Radio Communications I</strong></td>
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<td><strong>23447</strong></td>
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<td>Associated Exercise</td>
<td>23449</td>
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<td>Lecturer/ Institute</td>
<td>Dr. Younis / IHE</td>
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<td>Credit Points</td>
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<td>Semester hours</td>
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<td>Elective course</td>
<td>Bachelor/Master</td>
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<td>Prerequisites</td>
<td>Basic knowledge of physics, electromagnetics, and communication systems.</td>
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**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 coupled 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
- elements of wireless communication systems
Antennas
- radiation mechanism of antennas
- 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.
Lecture notes
Material to the lecture can be found online at http://www.ihe.kit.edu/VorlesungenWS_859.php.

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
The lectures Advanced Radio Communications I and Advanced Radio Communications II complement each other. By combining both lectures the student obtains knowledge of both the physical as well as the signal processing basics necessary for radio communications. Nevertheless, the courses can be chosen independently and in arbitrary order. Current information can be found at the webpage of the IHE (www.ihe.kit.edu).
Course name: Spaceborne Microwave Radiometry

Course code: 23448

Lecturer/Institute: Prof. Süß / IHE

Credit Points: 3

Semester hours: 2

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 spaceborne platforms; demonstration of modern methods for the detection of antipersonal mines, detection of hidden explosives and weapons.

Brief description course: Microwave radiometry is the measurement of the natural, thermal, electromagnetic radiation of our environment. It is based on the atomic and molecular transitions of the matter at 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, operating frequency, polarisation and on 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 chain of the microwave radiometry on 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, air- and space borne platforms.

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.

Lecture notes: The notes will be distributed before the lectures.

Literature:
B. Vowinkel „Passive Mikrowellenradiometrie” Vieweg-Verlag

Language: English

Examination: Oral (see actual document “Studienplan” and notice of the examination office ETIT).

Formation of grade: Grades result from the oral examination.
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<td>Actual information can be found at the internet page of the IHE (<a href="http://www.ihe.kit.edu">www.ihe.kit.edu</a>).</td>
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</tbody>
</table>
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 on after a brief introduction to optical communication systems on pin and avalanche 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
- Noise
- Receivers and detection errors
- Direct reception (Analogue reception. Digital reception. Detection errors through noise. Limits of detection) Direct, heterodyne and homodyne reception compared (Reception without optical amplifier. Reception with optical amplifier) Calculation of direct receiver (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**


**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


Optical amplifiers
Semiconductor amplifier (Fabry-Perot amplifier. Travelling-wave amplifier) ¼ Doped fibre amplifier ¼ Optical amplifier noise (Noise figure)

Supplementary material
Summaries, problems and quizzes ¼ 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

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)
- Waves and modes (LPnm-modes, Parabolic profile)
- 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
- Near-field and far-field
- Group delay dispersion (Group delay, Profile optimization)
- Impulse response (Transfer function, Singlemode impulse response, Singlemode power impulse response, Multimode power impulse response, Group delay power transfer function)
- Fibre imperfections and mode coupling
- Bandwidth-length product
- Coupling devices (Light sources and fibres, Butt coupling, 70-%-excitation)
- Optical branches (Multimode interference (MMI) coupler, Directional coupler)
- 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)

Uniqueness of Helmholtz equation

Paraxial optics (Gauss-Laguerre fields, Gaussian beam and spherical resonators, ABCD matrix)

Coherence of optical fields

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


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).
<table>
<thead>
<tr>
<th>Course name</th>
<th>Einführung in die Quantentheorie für Elektrotechniker mit Übungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23474</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Grau / IPQ</td>
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<tr>
<td>Credit Points</td>
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<td>Semester hours</td>
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<tr>
<td>Brief description course</td>
<td>Introduction to theory including latest developments</td>
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<tr>
<td>Brief description exercises</td>
<td>Examples illustrate use of theoretical considerations</td>
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<td>Contents</td>
<td>Duality wave/particle</td>
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<td></td>
<td>Dirac’s bracket formalism</td>
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<td></td>
<td>Probabilities, expectation values</td>
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<tr>
<td></td>
<td>Uncertainty relations, complementarity</td>
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<tr>
<td></td>
<td>Spooky action at a distance, entangled states</td>
</tr>
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<td>Quantization of systems</td>
</tr>
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<td></td>
<td>The lecturer reserves the right to alter the contents of the course without prior notification.</td>
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<tr>
<td>Lecture notes</td>
<td>Script as pdf-file for download</td>
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<tr>
<td>Language</td>
<td>German, if majority wishes also in english</td>
</tr>
<tr>
<td>Examination</td>
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<td>Current information can be found on the IPQ (<a href="http://www.ihq.uni-karlsruhe.de/index_en.htm">http://www.ihq.uni-karlsruhe.de/index_en.htm</a>) webpage.</td>
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<tr>
<td>Course name</td>
<td>Quantum Functional Devices and Semiconductor Technology</td>
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<td>---------------------------------</td>
<td>---------------------------------------------------------</td>
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<tr>
<td>Course code</td>
<td>23476</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr. Walther/ IPQ</td>
</tr>
<tr>
<td>Credit Points</td>
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<tr>
<td>Objectives</td>
<td>Basics of quantum effect devices</td>
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<tr>
<td>Brief description course</td>
<td>Quantum effects in semiconductors and quantum functional devices (transistors, lasers and detectors) as well as device fabrication technology.</td>
</tr>
<tr>
<td>Brief description exercises</td>
<td></td>
</tr>
<tr>
<td>Contents</td>
<td>Fundamental properties of quantum functional devices Heterostructures 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</td>
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<tr>
<td>Language</td>
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<td>Examination</td>
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<td>Current information can be found on the IPQ (<a href="http://www.ihq.uni-karlsruhe.de/index_en.htm">http://www.ihq.uni-karlsruhe.de/index_en.htm</a>) webpage.</td>
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</table>
Course name: Laser Metrology

Course code: 23478

Lecturer/Institute: Dr. Eichhorn
Credit Points: 3
Semester hours: 2
Term: Bachelor/Master
Compulsory course: Bachelor/Master

Objectives: The student, knows the fundamental properties of laser light, has the necessary knowledge for understanding the information accessible by laser metrology, understands the fundamentals of the different detectors and their limits, has the necessary knowledge of several laser-metrological setups: Moiré, range and velocity measurements, absorption and scattering techniques.

Contents:
1 Laser diagnosis - theoretical considerations
   1.1 Laser beam properties - basic definitions
      1.1.1 Comparative evaluation of lasers and thermal radiation sources
      1.1.2 Laser beam radiance and spectral radiance
      1.1.3 Radiation laws
   1.2 Coherence properties of laser light sources
   1.3 Mathematische Formulierung der Kohärenzfunktion
   1.4 Spektrale Emission von Lasern
   1.5 Bestimmung der Modenstruktur
   1.6 Modenstruktur-Beeinflussung, Modenselektion
   1.7 Experimentelle Kohärenzlängenbestimmung
   1.8 Einfluss der Frequenzdrift auf die Kohärenzlänge
   2 Messtechnisch nutzbare Information
      2.1 Ausbreitung in homogenen isotropen Medien
      2.2 Ausbreitung in inhomogenen Medien
      2.3 Ausbreitung in anisotropen Medien
      2.4 Weitere messtechnische Möglichkeiten
   3 Strahlendiagnostik
      3.1 Fotoelektrische Detektoren
      3.2 Informationstheoretische Überlegungen
      3.3 Granulationseigenschaften des Laserlichtes
   4 Laser-Interferometrie
      4.1 Grundlegende Betrachtungen
      4.2 Zweistrahl-Interferometer
      4.3 Laser-Interferometrie in der Plasmaphysik
      4.4 Zwei- und Mehrwellenlängen-Interferometrie
   5 Laser-Gyroskope
      5.1 Grundprinzip der Moiré Deflektometrie
      5.2 Fresnel- bzw. Fraunhofer Beugung
      5.3 Anwendungsbereiche der Moiré-Technik
      5.4 Bewertung der Moiré -Verfahren
   6 Laser-Entfernungsmessung
      6.1 Einleitung
      6.2 Grundlegende Betrachtungen
      6.3 Einfluss der Atmosphäre auf die Ausbreitung
      6.4 Optische Entfernungsmessverfahren
      6.5 Messgenauigkeit
      6.6 Empfindlichkeit
      6.7 Heterodyn-Empfang
6.8 Ausgewählte Heterodynempfangs-Schaltungen
6.9 Tomoskopie
7 Laser-Geschwindigkeits-Messverfahren
  7.1 Prinzip der Dopplerverschiebung
  7.2 Strömungsmessung, Dopplerverschiebung
  7.3 Strömungsmessung mit Zweifokus-Verfahren
  7.4 Strömungsmessungen mit Laseranemometrie
  7.5 Abbildende, zeitaufgelöste Teilchenspur –
      Anemometrie
8 Absorptions- und Streulicht-Verfahren
  8.1 Absorptionsverfahren
  8.2 LIDAR, grundlegende Betrachtung
  8.3 Streuprozesse in der Laserdiagnostik
  8.4 Verfahren, basierend auf spontaner Streuung
  8.5 Spektroskopische Verfahren
  8.6 Übergang zu stimulierter Streuung
  8.7 Grundlagen der "Nichtlinearen Optik"
  8.8 Nonlinear optical laser light scattering diagnostic techniques

Lecture notes
Script, A. E. Siegman, Lasers , (University Science Books)
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
<table>
<thead>
<tr>
<th>Course name</th>
<th>Laser Metrology II</th>
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<tbody>
<tr>
<td>Course code</td>
<td>23479</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Hugenschmidt/ IPQ</td>
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<td>Term</td>
<td>Winter-/ Summer-term</td>
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<tr>
<td>Objectives</td>
<td>The goal is to relay theoretical fundamentals.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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.</td>
</tr>
<tr>
<td>Brief description exercises</td>
<td>n/a</td>
</tr>
</tbody>
</table>
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, Gabor's "inline" holography and "off-axis" holography according to Leith and Upatnieks. Mathematical description and experimental approach related to optical wave front recording and reconstruction.


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

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 addresses 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

Term: Summer term

Bachelor/Master: 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

Light sources

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

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
Prerequisites: Mathematics I and II, Fourier Transform

Objectives: The goal is to relay theoretical fundamentals.

Brief description of 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 of 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.


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.
Communications Engineering I

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
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).

Lecture notes

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 architecure 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 earth 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 lecture 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

**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 are 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.
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.
Communications Engineering II

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 of 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 of 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.

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
<table>
<thead>
<tr>
<th>Course name</th>
<th><strong>Selected Topics in Communications</strong></th>
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<tr>
<td>Course code</td>
<td><strong>23512</strong></td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Dr. Jäkel / INT</td>
</tr>
<tr>
<td>Credit Points</td>
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<tr>
<td>Semester hours</td>
<td>3</td>
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<tr>
<td>Prerequisites</td>
<td>Communications 1, Probability Theory</td>
</tr>
<tr>
<td>Objectives</td>
<td>The goal is to teach scientific writing and presentation</td>
</tr>
<tr>
<td>Brief description course</td>
<td>Working out a technical topic, writing a paper, presentation</td>
</tr>
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### 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 of the 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 milestones and project interfaces to groups inside the team. During the semester, the progress of the team is presented to the supervisors and other team members.

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: Laboratory Communications Systems

Course code: 23517

Lecturer/Institute: Prof. Dr. Jondral and assistants
Credit Points: 6
Semester hours: 4
Term: Winter semester
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 of 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. FIR multi rate filters
   FIR filters; FIR filters in the frequency domain; FIR filters with linear phase; design of linear phase FIR filters by fourier approximation; FIR multi rate filters
5. Hilbert transform, analytic signal, and the CORDIC algorithm
   CORDIC-algorithm; Hilbert transform and analytic signal; the Parks / McClellan design method; down sampling on bandpass signals employing quadrature networks; time-lapsed sampling
6. 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
7. Digital modulation modes
   ASK, PSK, DPSK, QAM; impulse forming, eye pattern; disturbance by AWGN; detectors
   Coding
   Introduction to source coding, channel coding, and cryptography

Lecture notes: The participants are provided with a detailed laboratory manual.
Language: German
Examination: Oral examination (about 30 min.) following the last experiment.
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 16 per winter semester. |
Signal Processing in Communications

**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:
The lecture discusses the fundamentals of information theory, especially focussing on their application in communications.

Brief description of 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

<table>
<thead>
<tr>
<th>Lecturer/ Institute</th>
<th>Dr. Jäkel / INT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit Points</td>
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</tr>
<tr>
<td>Semester hours</td>
<td>2+1</td>
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<tr>
<td>Term</td>
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<td>Bachelor/Master</td>
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<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>Signal Processing, Probability Theory, Basic knowledge of communications</td>
</tr>
</tbody>
</table>

## Objectives
Theoretical fundamentals of digital wireless communications are to be covered. The lecture discusses the application of digital signal processing in communications. For this purpose, new perspectives are added to already known topics and problems are covered, which were not part of basic signal processing and telecommunications courses.

## Brief description course
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.

## 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

## General remarks
The lectures Advanced Radio Communications I and Advanced Radio Communications II complement each other. By combining both lectures the student obtains knowledge of both the physical as well as the signal processing basics necessary for radio communications. Nevertheless, the courses can be chosen independently and in arbitrary order.
### Tasks for Engineers in Modern Companies

<table>
<thead>
<tr>
<th>Course name</th>
<th>Tasks for Engineers in Modern Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23541</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Dr.-Ing. Helmut Klausing / VDE Verband der Elektrotechnik</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3</td>
</tr>
<tr>
<td>Semester hours</td>
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<td>Term</td>
<td>Winter term</td>
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<tr>
<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Key Qualification</td>
</tr>
</tbody>
</table>

#### 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
**Two dimensional Signals and Systems**

### Course code
**23543**

### Lecturer/ Institute
Prof. Dr. rer. nat. Maurus Tacke / Fraunhofer IOSB

### Credit Points
3

### Semester hours
2

### Term
Winter term

### Bachelor/ Master
Bachelor/Master

### Elective course
Bachelor/Master

### 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.

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<thead>
<tr>
<th>Lecture notes</th>
<th>Online material is available on: <a href="http://www.estudium.org">www.estudium.org</a></th>
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<td>Language</td>
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<tr>
<td>Examination</td>
<td>Written (see actual document “Studienplan” and notice of the examination office ETIT).</td>
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<tr>
<td>Formation of grade</td>
<td>Grades result from the written examination</td>
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<td>Course form</td>
<td>Lecture and Exercises</td>
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<tr>
<td>General remarks</td>
<td>The course comprises of the interleaved lecture blocks, exercises, and tutorials. Current information can be found on the ITIV (<a href="http://www.itiv.kit.edu">www.itiv.kit.edu</a>) webpage and within the eStudium-teachingplatform (<a href="http://www.estudium.org">www.estudium.org</a>).</td>
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<tr>
<td>Course name</td>
<td>OFDM Based Transmission Techniques</td>
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<td>23545</td>
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<tr>
<td>Dozent / Institut</td>
<td>Dr. Michael Schnell / DLR</td>
</tr>
<tr>
<td>Credit Points</td>
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<td>Bachelor/Master</td>
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<td>Elective course</td>
<td>Bachelor/Master</td>
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<td>Prerequisites</td>
<td>Basic knowledge in communications</td>
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<tr>
<td>Objectives</td>
<td>The goal is to relay the theoretical fundamentals of multi-carrier communications.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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.</td>
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<tr>
<td>Contents</td>
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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.
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 examination

Formation of grade: Grades result from oral examination.

Course form: Lecture
Course name: Channel Coding

Course code: 23546

Lecturer/ Institute: Prof. Dr.-Ing. Bernd Friedrichs / Tesat-Spacecom

Credit Points: 3
Semester hours: 2

Term: Summer term
Bachelor/ Master: Bachelor/Master
Elective course: Bachelor/Master

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

**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.

### 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.
<table>
<thead>
<tr>
<th>Language</th>
<th>German / English (according to the preferences of the audience)</th>
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</thead>
<tbody>
<tr>
<td>Examination</td>
<td>Oral (see actual document “Studienplan” and notice of the examination office ETIT).</td>
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<td>Formation of grade</td>
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<td>Course form</td>
<td>Lecture</td>
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</table>
Course name: Multirate Systems

Course code: 23548

Associated Exercise: 23549

Lecturer/Institute: Prof. Dr.-Ing. H.G. Göckler, Ruhr-Universität Bochum

Credit Points: 3+1,5

Semester hours: 2+1

Term: Winter term

Bachelor/Master: Bachelor/Master

Elective course: Bachelor/Master

Prerequisites: 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.


Applications (CATV system, satellite communications); Challenging exercises with detailed standard solutions supplemented with share-ware MATLAB routines in Internet

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: Introduction and overview about methods and tools for computer aided system- and software design.

Brief description course: Major topics are techniques and methods for the design of complex electric, electronic and electronic programmable 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: In association to the lecture, the exercise session express exercises concerning the lecture topics and discusses cases of application. 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. It will introduce to students the tools, which allow for a structured solution to 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 thematizes security and operability of complex electronical systems covering their complete lifetime. Mathematical modeling methods as well as risk analysis and simplified presentations like 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 the ENBF.

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.

<table>
<thead>
<tr>
<th>Lecture notes</th>
<th>Online material is available on: ilias.studium.kit.edu</th>
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<tbody>
<tr>
<td>Language</td>
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<tr>
<td>Examination</td>
<td>Written (see actual document “Studienplan” and notice of the examination office ETIT).</td>
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<td>Formation of grade</td>
<td>Grades result from the written examination</td>
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<tr>
<td>Course form</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>General remarks</td>
<td>The course comprises of the interleaved lecture blocks, exercises, and tutorials. Current information can be found on the ITIV (<a href="http://www.itiv.kit.edu">www.itiv.kit.edu</a>) webpage and within the ILIAS platform (ilias.studium.kit.edu).</td>
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<tr>
<td>Course name</td>
<td>System Analysis and Design</td>
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<tr>
<td>Course code</td>
<td>23606</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Müller-Glaser / ITIV</td>
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<tr>
<td>Credit Points</td>
<td>3</td>
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<tr>
<td>Semester hours</td>
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<td>Term</td>
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<td>Bachelor/ Master</td>
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<td>Elective course</td>
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<tr>
<td>Prerequisites</td>
<td>Basic knowledge of embedded systems is beneficial</td>
</tr>
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</table>

**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 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.

**Lecture notes**
Online material is available on: https://ilias.studium.kit.edu/goto_produktiv_crs_186475.html.

**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 Ilias-teachingplatform (https://ilias.studium.kit.edu).
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:
The aim of this lecture is to provide the students with knowledge about CAE tools and their backgrounds. To establish a more practical view, the lecture is supported by a demonstration of the tools.

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.

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.

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.

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

Lecture notes  Material for the lecture is provided online at ilias.studium.kit.edu. 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 (ilias.studium.kit.edu).
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<tr>
<th>Course name</th>
<th>System-On-Chip Laboratory</th>
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<tbody>
<tr>
<td>Course code</td>
<td>23612</td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Becker – ITIV / Prof. Siegel - IMS</td>
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<tr>
<td>Credit Points</td>
<td>6</td>
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<tr>
<td>Semester hours</td>
<td>4</td>
</tr>
<tr>
<td>Term</td>
<td>Winter and summer term</td>
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<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
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<tr>
<td>Elective course</td>
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<tr>
<td>Prerequisites</td>
<td>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)</td>
</tr>
<tr>
<td>Objectives</td>
<td>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.</td>
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<tr>
<td>Brief description</td>
<td>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.</td>
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</table>
| 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 implementation has to be done. Therefore state of the art tools are applied such
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 place and route process of the SoC can be started, using Cadence’s.

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.

Lecture notes Online material is available on: https://ilias.studium.kit.edu/
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 ILIAS teaching platform (https://ilias.studium.kit.edu/).
Course name: Digital System Design

Course code: 23615

Associated Exercise: 23617

Lecturer/ Institute: Prof. Becker / ITIV

Credit Points: 4.5 + 1.5

Semester hours: 3 + 1

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.

Lecture notes
Online material is available on: ilias.studium.kit.edu

Literature: Hans Martin Lipp, Jürgen Becker; Grundlagen der Digitaltechnik; 7., überarbeitete Auflage 2011.

Language
German

Examination
Written, 2 Hours (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 ILIAS-teachingplatform (ilias.studium.kit.edu).
Course name: Communication Systems and Protocols

Course code: 23616

Associated Exercise: 23618

Lecturer/ Institute: Prof. Becker, Dr. Klimm / ITIV

Credit Points: 3 + 1,5

Semester hours: 2 + 1

Term: Summer term

Bachelor/ Master: Master

Elective course: Master

Prerequisites: This lecture builds upon the lecture „Digital System Design“ (Lecture no. 23615),

Objectives: The goal of this lecture is to introduce basic concepts of communication systems and their protocols, and to work out common aspects. Some typical and popular solutions are covered 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 these 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.

Contents: This lecture for students of electrical engineering and information technology gives an insight into theory and application of today’s and future data exchange in and between computers as well as dedicated communication systems. Differing systems for a broad spectrum of possible applications are presented, ranging from embedded systems to computer networks. 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 safety 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 Ethernet, PCI-Express, FireWire, USB, I2C und CAN.

Lecture notes: Online material is available on https://ilias.studium.kit.edu/repository.php?cmd=frameset&ref_id=167257

Literature: Bernd Schürmann; Grundlagen der Rechnerkommunikation; 1. Auflage 2004. Friedrich Wittgruber; Digitale Schnittstellen und Bussysteme, 2002

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 and exercises. Actual information can be found on the ITIV (http://www.itiv.kit.edu) webpage and within the Illias-teachingplatform (https://ilias.studium.kit.edu).
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

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 datapaths
- 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
- Floorplanning-, routing- and placement methods
- Global and detailed wiring mechanisms
- Rapid-Prototyping
- Emulation/simulation, technology and ascertained prototyping-systems,
- Application examples
<table>
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<tr>
<th>Lecture notes</th>
<th>Online material is available on: <a href="https://ilias.studium.kit.edu">https://ilias.studium.kit.edu</a></th>
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<tbody>
<tr>
<td>Language</td>
<td>German</td>
</tr>
<tr>
<td>Examination</td>
<td>Oral (see actual document “Studienplan” and notice of the examination office ETIT)</td>
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<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
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<tr>
<td>Course form</td>
<td>Lecture and Exercises</td>
</tr>
<tr>
<td>General remarks</td>
<td>The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the ITIV (<a href="http://www.itiv.kit.edu">www.itiv.kit.edu</a>) webpage and within the eStudium-teaching platform (<a href="https://ilias.studium.kit.edu">https://ilias.studium.kit.edu</a>).</td>
</tr>
</tbody>
</table>
**Course name:** Hardware/Software Codesign

**Course code:** 23620

**Associated Exercise:** 23622

**Lecturer/ Institute:** Dr. Sander / 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
- Processor design: Pipelining, superscalar, VLIW, SIMD, Cache, MIMD
- Microcontroller, DSP, GPU, ASIP, FPGA, System-on-Chip (SoC)
- Bussystems and Network-on-Chip (NoC)
- Estimation of design quality
- Hardware- and software-performance
- Methods for hardware/software partitioning
- Iterative and constructive heuristics

**Lecture notes:** Online material is available on: estudium.fsz.kit.edu

**Literature:**

**Language:** German
<table>
<thead>
<tr>
<th>Examination</th>
<th>Oral (see actual document “Studienplan” and notice of the examination office ETIT).</th>
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<td>Lecture and Exercises</td>
</tr>
<tr>
<td>General remarks</td>
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</tr>
</tbody>
</table>
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 explain the according 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. 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, as well as the basic programming paradigms, are presented.

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-oriented 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, a short 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.

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

Course form
Lecture, exercise and lab

General remarks
The course comprises the blocks: lecture, exercises and lab. Current information can be found on the ITIV (www.itiv.kit.edu) webpage and within the eStudium teaching platform (ilias.studium.kit.edu).
**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 beginning 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.


**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).
Lab Information Technology

Course code: 23626

Lecturer/Institute: Prof. Müller-Glaser / ITIV
Credit Points: 3
Semester hours: 2
Term: Winter 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 dealing with an integrated development environment. This includes the verification of source code by means of test programs.

Brief description course: The lab helps the students 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 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 project documentation according to given guidelines (planning, software and testing).


Language: German
Examination: Written Examination after the 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 Ilias teaching platform (https://ilias.studium.kit.edu).
<table>
<thead>
<tr>
<th>Course name</th>
<th>Seminar: Embedded Systems</th>
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<tbody>
<tr>
<td>Course code</td>
<td>23627</td>
</tr>
<tr>
<td>Lecturer/Institute</td>
<td>Prof. Stork / ITIV</td>
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<tr>
<td>Credit Points</td>
<td>3</td>
</tr>
<tr>
<td>Semester hours</td>
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<td>Term</td>
<td>Winter and summer term</td>
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<td>Bachelor/Master</td>
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<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
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<tr>
<td>Prerequisites</td>
<td>None</td>
</tr>
<tr>
<td>Objectives</td>
<td>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.</td>
</tr>
<tr>
<td>Brief description course</td>
<td>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.</td>
</tr>
<tr>
<td>Contents</td>
<td>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.</td>
</tr>
<tr>
<td>Language</td>
<td>German or English</td>
</tr>
<tr>
<td>Examination</td>
<td>Written (see actual document “Studienplan” and notice of the examination office ETIT).</td>
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<tr>
<td>Formation of grade</td>
<td>Grades result from the composition and the presentation.</td>
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<td>Course form</td>
<td>Seminar</td>
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<td>General remarks</td>
<td>Current information can be found on the ITIV webpage (<a href="http://www.itiv.kit.edu">www.itiv.kit.edu</a>).</td>
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<tr>
<td>Course name</td>
<td>Optical Engineering</td>
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<tr>
<td>Course code</td>
<td>23629</td>
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<tr>
<td>Associated Exercise</td>
<td>23631</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Stork / ITIV</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3 + 1.5</td>
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<tr>
<td>Semester hours</td>
<td>2 + 1</td>
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<tr>
<td>Term</td>
<td>Winter term</td>
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<tr>
<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>none</td>
</tr>
</tbody>
</table>

**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.

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<tbody>
<tr>
<td>Language</td>
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<tr>
<td>Examination</td>
<td>Oral (see actual document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the oral examination</td>
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<tr>
<td>Course form</td>
<td>Lecture and exercises</td>
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<tr>
<td>General remarks</td>
<td>The course comprises of the interleaved lecture blocks and exercises. Current information can be found on the ITIV (<a href="http://www.itiv.kit.edu">www.itiv.kit.edu</a>).</td>
</tr>
<tr>
<td>Course name</td>
<td>Integrated Smart Sensors</td>
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<tr>
<td>Course code</td>
<td>23630</td>
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<tr>
<td>Associated Exercise</td>
<td>None</td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Dr.-Ing. Stefan Hey, Prof. Stork / ITIV</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3</td>
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<td>Semester hours</td>
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<td>Term</td>
<td>Summer term</td>
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<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
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<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Prerequisites</td>
<td>No specific requirements</td>
</tr>
</tbody>
</table>

**Objectives**

The students obtain an insight in Smart Sensor functionality and technology as well as different application fields and their economic meaning.

**Brief description course**

Different sensing technologies and applications of Microsystems-technology are presented and evaluated.

**Contents**

In the lecture, applications of the various micro-technologies, such as micro-optics or micro-mechanics, are demonstrated by means of current examples from industry and research. The main topics of the lecture are microsensors and microactuators with integrated signal processing capabilities (“Smart Sensors”) for applications in the automobile and the manufacturing industry, as well as for environmental protection and biomedical technology.

Structure and operating modes of microsensors for acceleration, force, pressure, position, speed, temperature, as well as chemical and biological analysis are introduced. The various principles and concepts for magneto & electrostatic, piezoelectric, and thermo mechanic actuators are explained.

Additionally, the significance of microsystems technology for the current economic development is discussed.

**Lecture notes**

The slides of the lecture are available online on https://estudium.fsz.kit.edu/

**Literature:**

- Heyne, Georg: „Elektronische Messtechnik: eine Einführung für angehende Wissenschaftler“, Oldenbourg, 1999,
- Hoffmann, J: „Handbuch der Messtechnik“, Hanser, München, 1999,

**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).
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<tr>
<th><strong>Course name</strong></th>
<th>Seminar: How to Invent and Apply for a Patent</th>
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<tr>
<td><strong>Course code</strong></td>
<td>23633</td>
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<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Prof. Stork / ITIV</td>
</tr>
<tr>
<td><strong>Credit Points</strong></td>
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</tr>
<tr>
<td><strong>Semester hours</strong></td>
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<tr>
<td><strong>Term</strong></td>
<td>Winter and summer term</td>
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<tr>
<td><strong>Bachelor/ Master</strong></td>
<td>Bachelor/Master</td>
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<tr>
<td><strong>Elective course</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Prerequisites</strong></td>
<td>Fun with new ideas.</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Brief description course</strong></td>
<td>To pen a written patent application.</td>
</tr>
<tr>
<td><strong>Contents</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Language</strong></td>
<td>German</td>
</tr>
<tr>
<td><strong>Examination</strong></td>
<td>Written (see actual document “Studienplan” and notice of the examination office ETIT).</td>
</tr>
<tr>
<td><strong>Formation of grade</strong></td>
<td>Grades result from the self-written patent application.</td>
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<tr>
<td><strong>Course form</strong></td>
<td>Seminar</td>
</tr>
<tr>
<td><strong>General remarks</strong></td>
<td>Current information can be found on the ITIV webpage (<a href="http://www.itiv.kit.edu">www.itiv.kit.edu</a>).</td>
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</tbody>
</table>
Sensor Systems for applications in fitness and sports

Course code: 23634

Lecturer/ Institute: Dr. Stefan Hey / ITIV
Credit Points: 3
Semester hours: 2
Term: Winter term
Bachelor/ Master: Bachelor/Master
Elective course: Bachelor/Master
Prerequisites: none

Objectives: The aim of the course „Sensor Systems for applications in fitness and sports“ is that the students are able to prepare a given topic independently. This contains a focused literature research, the analysis of given information as well as a written summary and an oral presentation of the results.

Contents: During the last years a number of sensor based applications for fitness and competitive sports has been developed and successfully placed on the market. The seminar deals with current topics from research and development of sensor systems for sports applications. The focuses of the seminar are mobile, wireless connected and interactive sensor systems for monitoring physical activity and physiological parameters which are used for the estimation of physical efficiency. Due to the character of this seminar, a key aspect of the work is the interdisciplinary examination of the theme. Beside the technical possibilities of realizing such systems, requirements of the users as well as economical aspect have to been taken into account.

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

Lecture notes: Online material is available on: estudium.fsz.kit.edu;
Language: German
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
Praktikum Entwurfsautomatisierung

Course name

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 microcontrollers and FPGA designs. Using modern design tools, typical design steps on various abstraction levels are carried out and practiced.

Brief description of course
In two person teams during several meetings the students will familiarize with the design of complex hardware/software systems. Beginning with simple finite state machines, through 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 a 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 coffeemaker. The exercise is based on a MSP430 microcontroller. Students familiarize themselves with AD conversion of a pulse signal, its signal processing, controlling of a RFID card reader and programming of an interface to PC.

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 implement 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 implemented 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.

Lecture notes  Online material is available on: estudium.fsz.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 (70%) and exercise reports (30%)  
Course form  Laboratory  
General remarks  Current information can be found on the ITIV (www.itiv.kit.edu) webpage.
**Course name**: Laboratory Circuit Design

**Course code**: 23638

**Lecturer/ Institute**: Prof. Dr.-Ing. Jürgen Becker / ITIV  
Dr.-Ing. Oliver Sander / ITIV

**Credit Points**: 6  
**Semester hours**: 4  
**Term**: Bachelor/Master  
**Compulsory course**: Bachelor/Master  
**Elective course**: Systems Engineering, System-on-Chip  
**Prerequisites**: Basic knowledge of electronic circuits (e.g. LEN, course code 23256, ES, course code 23655 and EMS, course code 23307)

**Objectives**: The laboratory provides knowledge and skills required to design electronic circuits that can be used as interface between microcontrollers/FPGAs and sensors/actuators. At the end of the laboratory the participants are able to select electronic parts for a given problem by means of relevant criteria. They are able to combine them into elementary modules and finally to a working overall system. Besides the circuit design also basic methods and skills for PCB layouts are introduced. Further the participants learn to assemble and test the designed circuits in reality.

**Brief description course**: The course is organized as a laboratory running three weeks fulltime. The objective of the laboratory is the development and assembly of all electronic parts required for a self-balancing, uniaxial vehicle. The first part of the laboratory is organized like an ordinary lecture where frequently used fundamental electronic circuits are discussed. In the following part several teams of two students each create sub circuits which are combined to the overall system at the end of the laboratory and are finally tested.

**Contents**: The first part of the laboratory is organized like a lecture and focuses on fundamental electronic circuits. Discussed circuits are (amongst others) power supplies, clock generation, conditioning of sensor inputs, power electronics and access of displays. Besides the presentation of the individual circuits it selves also an overview of electronic parts usually used for the circuit is given. Great importance is given to the discussion of real parts by means of their official datasheets. From time to time practical exercises are inserted into the lecture where the students build the discussed circuits on a patch panel to strengthen the gained knowledge. Therefore a large assortment of common electronic parts is available which can be used for the experiments. The purpose of this first part of the laboratory is the refreshment of knowledge already present from other courses and to provide practical handling skills of frequently used basic circuits.

After the discussion of fundamental circuits, a short introduction to PCB layout follows. Besides the training with the layout software used during the laboratory, also hints for place and route of electronics parts are given. At the same time topics like minimization of noise and crosstalk, placement of blocking capacitors and ground planes are discussed.

During the third and longest part of the laboratory, teams of two students each create first a concept, a schematic and finally a layout of a part of the overall system. Only the exact requirements for the sub circuit to implement and the interfaces to other sub circuits are defined. All further steps in the development are done preferably autonomous by the students, based on the knowledge from the first part of the laboratory.
At defined stages of the development process (e.g. after the creation of the schematic) the current status of the individual teams is given in a short presentation or discussed in the form of a peer review.

In the last stage of the laboratory the developed layouts are manufactured in the workshop of the institute, assembled with components, and tested by the students themselves. If all required sub circuits are completed, they are combined to the overall system and finally verified by a test drive with the vehicle.

Besides providing practical expert knowledge also the development of team competence is an important part of the laboratory. Because the individual parts of the overall system are created by different teams, a mutual solution of problems and therewith a vivid exchange of information is indispensable.

Lecture notes  Online material is available on: estudium.fsz.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 (70%) and presentations given while the laboratory (30%)
Course form  Laboratory
General remarks  Current information can be found on the ITIV website (www.itiv.kit.edu)
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 system design (e.g. LV 23605) and software engineering (e.g. LV 23611); 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.

Lecture notes
Online material is available on: https://ilias.studium.kit.edu 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 iLIAS teaching platform (https://ilias.studium.kit.edu).
**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 electronic 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 a) typical requirements for avionics systems, consisting of technically measurable and of functionally verifiable parameters as well as b) requirements for the development process itself and c) requirements for the quality management. The process of the product development, which supports the complete implementation of all requirements, is divided into phases. These phases are well defined including all related activities and goals of the individual phase as well as the criteria for the completion of a phase and the available documentation. The process ends with the verification, that the developed product fulfils all requirements as identified at the beginning.

The second part, the project management, explains different structures of the organization and in detail the tasks of a project manager. The most important task is the permanent balance of the three essential targets quality, cost and schedule. For the accomplishment of these permanent conflicts the lecture provides various tools and especially a systematic planning, control and continuous check. Finally, a few aspects of communication and intercultural project management are presented.

The topics are based on numerous examples and experience reports from the field shown.

**Lecture notes**  
Material will be distributed during 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

**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.
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.

<table>
<thead>
<tr>
<th>Lecture notes</th>
<th>Online material is available on: estudium.fsz.kit.edu and <a href="http://www.itiv.kit.edu">www.itiv.kit.edu</a></th>
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</thead>
<tbody>
<tr>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Examination</td>
<td>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).</td>
</tr>
<tr>
<td>Formation of grade</td>
<td>Grades result from the written examination. Participation in the laboratory / tutorial is mandatory for the registration to the written examination</td>
</tr>
<tr>
<td>Course form</td>
<td>Lecture / Laboratory</td>
</tr>
<tr>
<td>General remarks</td>
<td>Current information can be found on the ITIV (<a href="http://www.itiv.kit.edu">www.itiv.kit.edu</a>) webpage and within the eStudium teaching platform (estudium.fsz.kit.edu).</td>
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</tbody>
</table>
The laboratory gives a practical insight to the cycle of microcontrollers and FPGA designs. Using modern design tools, typical design steps on various abstraction levels are carried out and practiced.

In two person teams during several meetings the students will familiarize with the design of complex hardware/software systems. Beginning with simple finite state machines, through processor design to a real power window control of an S-Class Mercedes.

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 coffeemaker. The exercise is based on a MSP430 microcontroller. Students familiarize themselves with AD conversion of a pulse signal, its signal processing, controlling of a RFID card reader and programming of an interface to PC.

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.

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Lecture notes Online material is available on: estudium.fsz.kit.edu
Language English
Examination Oral (see actual document “Studienplan” and notice of the examination office ETIT).
Formation of grade Grades result from the oral examination (70%) and exercise reports (30%)
Course form Laboratory
General remarks Current information can be found on the ITIV (www.itiv.kit.edu) webpage.
<table>
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<tr>
<th><strong>Course name</strong></th>
<th><strong>Optical Design Lab</strong></th>
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<tbody>
<tr>
<td><strong>Course code</strong></td>
<td><strong>23647</strong></td>
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<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Prof. Stork / ITIV</td>
</tr>
<tr>
<td><strong>Credit Points</strong></td>
<td>6</td>
</tr>
<tr>
<td><strong>Semester hours</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Term</strong></td>
<td>Winter term (first 5 assignments also in summer term)</td>
</tr>
<tr>
<td><strong>Bachelor/ Master</strong></td>
<td>Bachelor/Master</td>
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<tr>
<td><strong>Elective course</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Prerequisites</strong></td>
<td>Fundamentals of optics (attending the lecture „Optical Engineering“ during the same term is highly recommended)</td>
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</table>

**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 according to some given constraints using industry standard Optical Design software.

**Brief description course**
In this lab course, the participating students will have the opportunity to gain hands-on experience with 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 “Zemax”. The last two assignments are from the field of illumination design.

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 Zemax 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 non sequential mode of the Zemax to design, among others, the backlight for a LCD and a car headlight.

**Lecture notes**

**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 ILIAS teaching platform (https://ilias.studium.kit.edu/).
Course name: Test of Embedded Systems in Industry Context

Course code: 23648

Associated Exercise: 23649

Lecturer/Institute: Dr.-Ing. Stefan Schmerler (Daimler AG) / 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 aims to provide a basic knowledge on testing embedded systems. Thereby, we focus on software systems, however consider also hardware and mechatronic aspects. Based on the theoretical basics of testing, concrete applications of testing are provided (for example testing of Electronic Control Units (ECU) in the automotive engineering). Furthermore, state of the art tools as well as technologies are explained and demonstrated. Moreover, recent and previously published research approaches in this discipline are discussed. The contents of this course are very practical and can be used successfully by the students also in other domains, e.g. in standard software development.

Brief description course: The course provides knowledge on methods, technologies and procedures applied in testing software on embedded systems.

Brief description exercises: Accompanying the lecture, in the practical exercise the students exercises practical software testing. Thereby, actual tools for description and modeling of software tests are used.

Contents: Lecture

Basic principles and terms / definitions of testing: Why are software tests in the development of embedded systems of such importance? Major quality assurance arrangements are outlined and illustrated with typical studies. In this context, a detailed overview of analytical quality assurance is given.

Test phases and process: The main development and testing phase models are described. How to arrange a testing process, what kind of test activities are present and how are they characterized?

Dynamic testing: Different approaches to the systematic test case generation/derivation for dynamic testing are presented. Definition, metrics and empirical values for the amount of tests and test coverage are given.

Static testing: Different analytical quality assurance procedures are described in detail and related to each other. The theory of static testing is explained. All major static testing methods e.g. formal reviews, static analysis, symbolic execution, model checking, formal verification and simulation are characterized, related to each another and partially explained with examples.

Evolutionary testing: After discussion of the theoretical principles of evolutionary algorithms, different evolutionary based testing methods that are used in automotive engineering are explained and practical examples shown. Specifically, the evolutionary test of real-time behavior, the evolutionary structural software test, the evolutionary functional test and the evolutionary safety test are outlined.
Model-based testing: Current research and development approaches, e.g. Time Partition Testing or automatic model-based test case generation, are presented and partly explained on practical examples.

Test of real-time systems: First an introduction to the characteristics of real-time systems is given. In the next step we describe the details of planning real-time systems (including design for testability) and explain the structure and operation of real-time test programs. The current state of the art is described and an outlook on possible future research disciplines is given. As a special real-time test system, specific applications of hardware-in-the-loop technology in research are outlined, e.g. test of diver assistance systems in automotive engineering.

Exercise
In the exercise knowledge gained from lecture is applied in various tasks. In the first part practical problems in the field of reliability, fault tree analysis, failure rates and test phases are examined. Furthermore, reviews, quality metrics and different test methods are discussed.

In the second part different software test programs, which are used for example in automotive engineering, are used by the students to solve practical problems. Thereby, tests are created and analyzed using specific methods, e.g. classification tree analysis, for different scenarios and criteria.

In the next step, the developed tests are used to test software functions. In this context, test coverage is studied with regard to various criteria. Furthermore, different errors are analyzed and appropriate test reports generated.

In the last step model-based testing is applied. Thereby, the method of Time Partition Testing is used. The task of the students is to localize bugs in model-based development of embedded systems using model-based testing methods.

Lecture notes
Online material is available at: ilias.studium.kit.edu and www.itiv.kit.edu

Language
German

Examination
Oral examination (see actual document “Studienplan” and notice of the examination office ETIT).

Formation of grade
Grades result from the oral examination

Course form
Combination lecture & practical exercise

General remarks
Current information can be found on the ITIV webpage (www.itiv.kit.edu) and within the ILIAS teaching platform (ilias.studium.kit.edu).
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 of 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 of 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. Functional 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 integrated 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: 4.5

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 Cadence® Virtuoso full custom design environment. To understand and use the Cadence® simulation tools. To understand and use the Cadence® 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 Cadence® 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.
<p>| 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 (<a href="http://www.ims.kit.edu">www.ims.kit.edu</a>) webpage. |</p>
<table>
<thead>
<tr>
<th>Course name</th>
<th><strong>Nanoelectronics</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Course code</td>
<td>23668</td>
</tr>
<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Siegel / IMS</td>
</tr>
<tr>
<td>Credit Points</td>
<td>3</td>
</tr>
<tr>
<td>Semester hours</td>
<td>2</td>
</tr>
<tr>
<td>Term</td>
<td>Summer term</td>
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<tr>
<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
</tbody>
</table>

**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 Iwa 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.
<table>
<thead>
<tr>
<th><strong>Course name</strong></th>
<th>Laboratory Adaptive Sensor Electronics</th>
</tr>
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<tbody>
<tr>
<td><strong>Course code</strong></td>
<td>23672</td>
</tr>
<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Prof. Siegel / IMS</td>
</tr>
<tr>
<td><strong>Credit Points</strong></td>
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<tr>
<td><strong>Semester hours</strong></td>
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<tr>
<td><strong>Term</strong></td>
<td>Winter and summer term</td>
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<tr>
<td><strong>Bachelor/ Master</strong></td>
<td>Bachelor/Master</td>
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<tr>
<td><strong>Elective course</strong></td>
<td>Bachelor/Master</td>
</tr>
</tbody>
</table>

**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.
### Laboratory FPGA based Circuit Design

**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

Prerequisites: Basics in electronics and physics

Objectives:
- To understand the frequency ranges covered by different sources in space; principles of detection of light, radio waves, 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:
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 as 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.
<table>
<thead>
<tr>
<th>Course form</th>
<th>Lecture</th>
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<tbody>
<tr>
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<td>Current information can be found on the IMS (<a href="http://www.ims.kit.edu">www.ims.kit.edu</a>) webpage.</td>
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<tr>
<td>Course name</td>
<td>Seminar Embedded Circuits and Detectors</td>
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<tr>
<td>Course code</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Siegel / IMS</td>
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<td>Credit Points</td>
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<td>Semester hours</td>
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<td>Term</td>
<td>Winter and summer term</td>
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<td>Bachelor/ Master</td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td>Elective course</td>
<td>Bachelor/Master</td>
</tr>
</tbody>
</table>

**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.
<table>
<thead>
<tr>
<th><strong>Course name</strong></th>
<th><strong>Superconducting Systems</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Course code</strong></td>
<td><strong>23681</strong></td>
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<tr>
<td><strong>Lecturer/ Institute</strong></td>
<td>Prof. Noe / IMS (ITEP)</td>
</tr>
<tr>
<td><strong>Credit Points</strong></td>
<td>3</td>
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<tr>
<td><strong>Semester hours</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Term</strong></td>
<td>Winter term</td>
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<tr>
<td><strong>Bachelor/ Master</strong></td>
<td>Bachelor/Master</td>
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<tr>
<td><strong>Elective course</strong></td>
<td>Bachelor/Master</td>
</tr>
<tr>
<td><strong>Objectives</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Brief description course</strong></td>
<td>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&amp;D in superconductivity is rapidly increasing.</td>
</tr>
<tr>
<td><strong>Contents</strong></td>
<td>Basics of superconductivity</td>
</tr>
<tr>
<td></td>
<td>Superconducting phenomena</td>
</tr>
<tr>
<td></td>
<td>Stability of superconductors and loss mechanism</td>
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<tr>
<td></td>
<td>Characteristics and manufacturing of superconductors</td>
</tr>
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<td></td>
<td>Superconducting energy transmission</td>
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<td></td>
<td>Superconducting motors and generators</td>
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<td>Superconducting transformers</td>
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<td>Superconducting magnetic energy storage</td>
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<td>Superconducting magnets</td>
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<td>Superconducting electronic applications</td>
</tr>
<tr>
<td></td>
<td>Basics of cryogenics</td>
</tr>
<tr>
<td></td>
<td>The lecturer reserves the right to alter the contents of the course without prior notification.</td>
</tr>
<tr>
<td><strong>Lecture notes</strong></td>
<td>Online material is available on: <a href="http://www.ims.kit.edu">www.ims.kit.edu</a></td>
</tr>
<tr>
<td><strong>Language</strong></td>
<td>German</td>
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<tr>
<td><strong>Examination</strong></td>
<td>Oral</td>
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<tr>
<td><strong>Formation of grade</strong></td>
<td>Grades result from the oral examination</td>
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<tr>
<td><strong>Course form</strong></td>
<td>Lecture</td>
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<tr>
<td><strong>General remarks</strong></td>
<td>Current information can be found on the IMS (<a href="http://www.ims.kit.edu">www.ims.kit.edu</a>) webpage. At the end of the course an excursion is planned to KIT Campus North (ITEP).</td>
</tr>
</tbody>
</table>
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.

Brief description
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: 4.5

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.
<table>
<thead>
<tr>
<th><strong>Lecture notes</strong></th>
<th>Lecture slides are provided for download. Online material is available on: <a href="http://www.ims.kit.edu">www.ims.kit.edu</a> Digital Integrated Circuits, Jan M. Rabaey, Prentice Hall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Language</strong></td>
<td>German</td>
</tr>
<tr>
<td><strong>Examination</strong></td>
<td>oral</td>
</tr>
<tr>
<td><strong>Formation of grade</strong></td>
<td>Grades result from the oral examination. Prerequisite: submission of a written protocol of all exercise results.</td>
</tr>
<tr>
<td><strong>Course form</strong></td>
<td>Lecture, Exercises</td>
</tr>
<tr>
<td><strong>General remarks</strong></td>
<td>Current information can be found on the IMS (<a href="http://www.ims.kit.edu">www.ims.kit.edu</a>) webpage.</td>
</tr>
</tbody>
</table>
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
Software tools 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-digital 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 available under https://studium.kit.edu/

Language: German

Examination: Written 2h

Formation of grade: Grades results from the written examination

Course form: Lecture

General remarks: You will find the newest information online on https://studium.kit.edu/
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<tr>
<th>Course name</th>
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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
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Prerequisites: Bachelor

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<td>• Absorption and Scattering of Light by Small Particles, C. F. Bohren and D. R. Huffman, John Wiley&amp; Sons, INC. 1998</td>
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<td>Lecturer/ Institute</td>
<td>Dr. Michael Becker</td>
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<td>Credit Points</td>
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<td>The corresponding documents are available at <a href="http://www.displaymetrology.com">http://www.displaymetrology.com</a>. Access-data (user/pwd) are available after registration via eMail.</td>
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<tr>
<td>Course name</td>
<td><strong>Introduction into plasma technologies</strong></td>
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<td>Course code</td>
<td><strong>23734</strong></td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr. Rainer Kling / Professor Wolfgang Heering /LTI</td>
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<tr>
<td>Objectives</td>
<td>Basic knowledge on plasma technologies for coatings, semiconductor production and lamps</td>
</tr>
<tr>
<td>Brief description course</td>
<td>Einführungs vorlesung 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</td>
</tr>
<tr>
<td>Exercises</td>
<td>No Tutorial</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>The corresponding documents are avalible under <a href="https://studium.kit.edu/">https://studium.kit.edu/</a></td>
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<td>You will find the newest Information online on <a href="https://studium.kit.edu/">https://studium.kit.edu/</a></td>
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</table>
Course name: Optoelectronic 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 available 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: Photovoltaics

Course code: 23737

Lecturer/Institute: Prof. Dr.- Powalla
Credit Points: 4.5
Semester hours: 3
Term: Summerterm
Bachelor/Master: Bachelor/Master
Elective course: Bachelor/Master

Contents:

- The role of electrical energy from photovoltaics in national and global energy system scenarios (resources, emissions, PV market and costs)
- Physical fundamentals of energy conversion (solar radiation)
- Semiconductor physics (absorption of light, band structure, transport properties, recombination, optics)
- Energy conversion in semiconductors (p/n junction, theoretical limits, the electrochemical potential)
- Solar cells (characteristics, I/V curve, materials, losses)
- Realization concepts
  - Silicon technology, from quartz to the cell
  - Thin film solar cells
  - Concentrator cells, organic solar cells, dye sensitized solar cells
- Photovoltaic module and production technology
- Photovoltaic energy systems (components, converter, building integration, tracking systems)
- Energy performance, system efficiency and longtime stability

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
<table>
<thead>
<tr>
<th><strong>Course name</strong></th>
<th>Introduction in the technology of passive displays</th>
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</thead>
<tbody>
<tr>
<td><strong>Course code</strong></td>
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<td><strong>Lecturer/ Institute</strong></td>
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<td><strong>Semester hours</strong></td>
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The lecturer reserves the right to alter the contents of the course without prior notification.

**Lecture notes**
The corresponding documents are available 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/
<table>
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<tr>
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<td>Associated Exercise</td>
<td>23741</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Professor Cornelius Neumann / LTI</td>
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<tr>
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<td>optical technology in the automotive</td>
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<td>Brief description exercises</td>
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The lecturer reserves the right to alter the contents of the course without prior notification.

<p>| Lecture notes                   | The corresponding documents are available under <a href="https://studium.kit.edu/">https://studium.kit.edu/</a> |
| 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 <a href="https://studium.kit.edu/">https://studium.kit.edu/</a> |</p>
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<td>Lecturer/ Institute</td>
<td>Dr. Habil. Hans Eisler</td>
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<tr>
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<tr>
<th>Contents</th>
<th>Basics, Fundamentals, Volume: 3D-case</th>
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<tbody>
<tr>
<td></td>
<td>• General introduction and motivation</td>
</tr>
<tr>
<td></td>
<td>• Short history of nanoplasmonics</td>
</tr>
<tr>
<td></td>
<td>• Maxwell's Equations</td>
</tr>
<tr>
<td></td>
<td>• Optical properties of simple metals</td>
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<td>Nanoscale Surface: 2D-Case</td>
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<td>• Surface Plasmons and Surface Plasmon Polariton (SPP)</td>
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The lecturer reserves the right to alter the contents of the course without prior notification.

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<td>Course code</td>
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<td>You will find the newest information online on <a href="https://studium.kit.edu/">https://studium.kit.edu/</a></td>
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Course name: Photovoltaics

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 generation.

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.

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/
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<tbody>
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<td>Course code</td>
<td><strong>23746</strong></td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Dr. Rainer Kling, Prof. Dr. W. Heering</td>
</tr>
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<td>Credit Points</td>
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<td>Semester hours</td>
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<td>Bachelor/Master</td>
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<tr>
<td>Objectives</td>
<td>Light Sources and operating systems</td>
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<tr>
<td>Brief description course</td>
<td>Operational modes and principle circuits for plasma radiation sources, LED and solid state lasers</td>
</tr>
<tr>
<td>Contents</td>
<td>Electronic Circuits to drive lamps and Laser</td>
</tr>
<tr>
<td></td>
<td>Basics of coupling of electrical power, circuitry,</td>
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<tr>
<td></td>
<td>Characteristics of low- and high frequent ohmic operation</td>
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<tr>
<td></td>
<td>Equivalent circuit and electrical parameters</td>
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<td>Conventional lamp ballasts</td>
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<td>Transformer and transducto</td>
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<td>General remarks</td>
<td>You will find the newest Information online on <a href="https://studium.kit.edu/">https://studium.kit.edu/</a></td>
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</table>
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: The Light & Display Engineering lecture gives a broad overview of light engineering and display engineering 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

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/
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<th>Workshop Electrical Engineering and Information Technology I+II</th>
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<tr>
<td>Course code</td>
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<tr>
<td>Lecturer/ Institute</td>
<td>Prof. Zwick and academic staff / IHE</td>
</tr>
<tr>
<td></td>
<td>Prof. Siegel and academic staff / IMS</td>
</tr>
<tr>
<td></td>
<td>Prof. Müller-Glaser and academic staff / ITIV</td>
</tr>
<tr>
<td></td>
<td>Prof. Puente and academic staff / IIIT</td>
</tr>
<tr>
<td>Credit Points</td>
<td>Bachelor/Master</td>
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<td>Semester hours</td>
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<td>Term</td>
<td>Summer term / winter term</td>
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<td>Bachelor/ Master</td>
<td>Bachelor</td>
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<tr>
<td>Prerequisites</td>
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</tr>
<tr>
<td>Objectives</td>
<td>The team project is conducted at the beginning of the studies to relate the basic/fundamental courses with practical project work, in order to give a better understanding of the lecture contents. The basic practical tools which are required in the studies of electrical engineering are introduced. This includes signal theory, data acquisition and data evaluation, basic electronics or basic knowledge of µController programming.</td>
</tr>
<tr>
<td>Brief description</td>
<td>For the first time a team project is offered at the beginning of the studies (i.e. during the first 2 semesters). This is aimed to help students relate the fundamental courses with practical project work for a better understanding of the lecture contents. The fundamentals explored during this work will be of help not only during the course of the study but also for real world tasks e.g. in an engineering job. The team project consists of 4 practical courses in the field of electrical engineering, spread over 2 semesters. Students will work in groups of 2-4 and the outcome of the courses will in the form of a written report. Topics to be covered are circuit analysis using operational amplifiers, programming of µProcessors, sensors with adapted circuit designs for evaluation and signal sampling and analysis. Students can work at home with a special microcontroller board.</td>
</tr>
<tr>
<td>Contents</td>
<td>Teamlab: In all the tasks of the Team Project a micro-controller board with a signal generation and recording function is used. The experiments can thus be accomplished independently according to the task. The participating institutions are also available for support. In addition to that, at the beginning of the studies the software tool Matlab, which is very important for the electrical engineering study will be introduced.</td>
</tr>
<tr>
<td></td>
<td>1. Measurement recording and regenerative (1st semester) energy</td>
</tr>
<tr>
<td></td>
<td>Short description: In this experiment, students learn about the current issue of regenerative energy sources. For this purpose a solar cell is used in different practical applications in order to investigate the characteristics of photovoltaic and the benefits of energy storage. In the task, the optimal utilization of regenerative energy sources or the negative effects on solar panels such as shading are to be investigated. Additionally, through a lengthy experiment, the students will be exposed to basic Matlab functions and possibilities of data logging will be highlighted.</td>
</tr>
<tr>
<td></td>
<td>2. Analog filters and circuit analysis (2nd semester)</td>
</tr>
<tr>
<td></td>
<td>Short description:</td>
</tr>
</tbody>
</table>
Different basic operational amplifier circuits, as for example inverting, non-inverting and differential amplifiers, impedance converter or RC- and RL-networks are investigated and amplitude, frequency or phase responses are measured. In addition active filter (high-pass, low-pass, RCL-networks) are measured.

3. Sensors (2nd Semester)
Short description:
In this course, different sensors are analyzed. The general operation and theory of temperature, light or pressure sensors are introduced and in addition suitable circuits are examined to convert the physical values into proportional electrical signals as voltage or current. The content is adapted to the semester. Therefore only simple sensor principles are treated. For temperature measurement, temperature-dependent resistors or pn-junctions are studied. Applications for brightness measurements can be realized with LEDs, photodiodes and phototransistors. The experiment is divided into the following steps: understanding the sensor principle, design of evaluation circuits for sensor signals, simulation of circuits in LTSpice, comparative analysis of circuits and evaluation using the microcontroller board.

4. Programming and Signal Processing (2nd Semester)
Short description:
Another important part of the studies in the field of electrical engineering and information technology is programming. The goal of this course is to introduce to the students at the beginning of their studies the basics of system programming and signal theory. This includes microcontroller hardware basics such as embedded programming, controlling of peripheral units (IO ports, UART, ADC) and data acquisition and processing. In the field of signal processing, important aspects of signal theory such as the Fourier series, sampling theorem and quantization will be linked with the practice. In addition, the handling with Matlab will be extended.
Course name: Workshop Electrical Engineering and Information Technology I+II

Course code: 23902

Lecturer/ Institute:
- Prof. Zwick and academic staff / IHE
- Prof. Siegel and academic staff / IMS
- Prof. Müller-Glaser and academic staff / ITIV
- Prof. Puente and academic staff / IIIT

Bachelor/Master:
- Bachelor/Master

Credit Points:
- Bachelor/Master

Semester hours:
- 2

Term:
- Summer term / winter term

Bachelor/ Master:
- Bachelor

Compulsory course:
- yes

Prerequisites:
- none

Objectives:
The team project is conducted at the beginning of the studies to relate the basic/fundamental courses with practical project work, in order to give a better understanding of the lecture contents. The basic practical tools which are required in the studies of electrical engineering are introduced. This includes signal theory, data acquisition and data evaluation, basic electronics or basic knowledge of µController programming.

Brief description course:
For the first time a team project is offered at the beginning of the studies (i.e. during the first 2 semesters). This is aimed to help students relate the fundamental courses with practical project work for a better understanding of the lecture contents. The fundamentals explored during this work will be of help not only during the course of the study but also for real world tasks e.g. in an engineering job. The team project consists of 4 practical courses in the field of electrical engineering, spread over 2 semesters. Students will work in groups of 2-4 and the outcome of the courses will in the form of a written report. Topics to be covered are circuit analysis using operational amplifiers, programming of µProcessors, sensors with adapted circuit designs for evaluation and signal sampling and analysis. Students can work at home with a special micro-controller board.

Contents:
Teamlab:
In all the tasks of the Team Project a micro-controller board with a signal generation and recording function is used. The experiments can thus be accomplished independently according to the task. The participating institutions are also available for support. In addition to that, at the beginning of the studies the software tool Matlab, which is very important for the electrical engineering study will be introduced.

1. Measurement recording and regenerative (1st semester) energy
Short description:
In this experiment, students learn about the current issue of regenerative energy sources. For this purpose a solar cell is used in different practical applications in order to investigate the characteristics of photovoltaic and the benefits of energy storage. In the task, the optimal utilization of regenerative energy sources or the negative effects on solar panels such as shading are to be investigated. Additionally, through a lengthy experiment, the students will be exposed to basic Matlab functions and possibilities of data logging will be highlighted.

2. Analog filters and circuit analysis (2nd semester)
Short description:
Different basic operational amplifier circuits, as for example inverting, non-inverting and differential amplifiers, impedance converter or RC- and RL-networks are investigated and amplitude, frequency or phase responses are measured. In addition active filter (high-pass, low-pass, RCL-networks) are investigated and amplitude, frequency or phase responses are measured.

3. Sensors (2nd Semester)

Short description:
In this course, different sensors are analyzed. The general operation and theory of temperature, light or pressure sensors are introduced and in addition suitable circuits are examined to convert the physical values into proportional electrical signals as voltage or current. The content is adapted to the semester. Therefore only simple sensor principles are treated. For temperature measurement, temperature-dependent resistors or pn-junctions are studied. Applications for brightness measurements can be realized with LEDs, photodiodes and phototransistors. The experiment is divided into the following steps: understanding the sensor principle, design of evaluation circuits for sensor signals, simulation of circuits in LTSpice, comparative analysis of circuits and evaluation using the microcontroller board.

4. Programming and Signal Processing (2nd Semester)

Short description:
Another important part of the studies in the field of electrical engineering and information technology is programming. The goal of this course is to introduce to the students at the beginning of their studies the basics of system programming and signal theory. This includes microcontroller hardware basics such as embedded programming, controlling of peripheral units (I/O ports, UART, ADC) and data acquisition and processing. In the field of signal processing, important aspects of signal theory such as the Fourier series, sampling theorem and quantization will be linked with the practice. In addition, the handling with Matlab will be extended.

Lecture notes
Lecture materials can be found online in ILIAS at https://ilias.studium.kit.edu/goto.Produktiv_cat_146475.html

Language
German

Examination
The experiments are accomplished in groups with the µController-Boards and the results presented in a written report. Students will receive help and support in the form of Tutors, forums and consultations with academic staff. The forums will also allow mutual help between the students. The written report (only one per group) is to be uploaded to ILIAS at the end of the course.

Formation of grade
No grade, uploaded written report as proof

Course form
Laboratory in groups of 3-4 students