PADERBORN UNIVERSITY

FACULTY FOR COMPUTER SCIENCE, ELECTRICAL ENGINEERING AND MATHEMATICS
DEPARTMENT OF ELECTRICAL ENGINEERING AND INFORMATION TECHNOLOGY

MODULE HANDBOOK
MASTER'S PROGRAM COMPUTER ENGINEERING V4 (CEMA V4)

DATE: 7. MÄRZ 2025

Inhaltsverzeichnis

1 Preamble and references

For technical reasons, the preamble of the module manual has been moved. It can be found under Examination Regulations and Module Handbooks under the item “Module Handbooks” on the pages of the Institute EIM-E. We kindly ask you to pay attention to this preamble.

If you have any questions regarding this module handbook or the preamble, please contact either.

- to the Examination Board Computer Engineering,
- to the Computer Engineering Student Advisors,
- to the Electrical Engineering Student Advisor, or
- to the PAUL Electrical Engineering Student Services.

Please also note that

1. this module handbook lists all modules provided according to the examination regulations, even if they are not offered in the corresponding semester.
2. this module manual contains the data of the date of creation. All information is without guarantee.

2 Compulsory Area

Compulsory Area	
Modules	* Advanced Networked Systems * Advanced Computer Architecture * Statistical Signals * Analysis and Design of Electronic Circuits * Project Group * Scientific Work Style
Catalogue advisor	
Credits ECTS	6
Learning objectives	

Advanced Networked Systems			
Advanced Networked Systems			
Module number: M.079.4096	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7035 Advanced Networked Systems	L2 Ex3	75	105	C	50/25

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Advanced Networked Systems:
Recommended Proficiencies
Knowledge of computer networks, operating systems, programming languages, C/C++ and Python programming in the Linux environment, and a keen interest in understanding how things work under the hood. Ability to read scientific papers professionally. Ability to code in a complex setting.

4 **Contents:**

Contents of the course Advanced Networked Systems:
The course will cover concepts and designs for modern networked systems adopted by the Internet and cloud data centers to meet the ever-increasing demands of data transfer and computation driven by big data and machine learning applications.

- Networking fundamentals (refresher)
- Data center networks (architectures, congestion control)
- Software-defined networks (SDN, OpenFlow)
- Programmable networks (P4, eBPF/XDP)
- Programmable network device architectures (RMT, SmartNICs)
- In-network computing (caching, aggregation)

5 **Learning outcomes and competences:**

Upon completion of this course, students will be able to

- gain knowledge of current research topics in networked systems.
- understand the design of these new networked systems technologies and reason about the design choices therein.
- build complex networked systems by applying some of these designs, analyze and evaluate the merits and limitations of these designs, and explain the design choices for the built systems.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	90-120 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Lin Wang
13	**Other Notes:** *Remarks of course Advanced Networked Systems:* **Implementation Method** The course content will be taught with slides-based lectures, interactive exercises, and programming-based project assignments. Much of the course will be based on discussions of cutting-edge research topics, complemented with hands-on programming assignments. **Learning Material, Literature** • Lecture slides and exercise sheets • Project description documents for the programming assignments • Additional literature (e.g., research papers) on the course website and in the lecture slides

Advanced Computer Architecture			
Advanced Computer Architecture			
Module number: M.079.4005	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7031 Advanced Computer Architecture	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Advanced Computer Architecture:
Recommended Proficiencies
Knowledge from the Bachelor course Computer Architecture is helpful.

4 **Contents:**

Contents of the course Advanced Computer Architecture:
The course teaches the essential concepts and methods used in the design of modern processors. In particular, advanced aspects of optimizing access times and throughput in the memory hierarchy, as well as approaches to exploiting parallelism at the instruction, data, and thread levels are discussed. The course covers the following topics:

- Fundamentals of computer architectures (refresher)
- Memory hierarchy design
- Instruction-level parallelism
- Data-level parallelism: Vector, SIMD and GPU architectures
- Thread-level parallelism
- Warehouse-scale computer
- Domain-specific computer architectures

5 **Learning outcomes and competences:**

Upon completion of this module, students will be able to

- explain the architecture of modern multi-level storage systems, mathematically model the average access time, and qualitatively describe and evaluate the influence of the main design parameters,
- explain the concepts of parallel processing at the data, instruction, thread and task levels and contrast algorithms for out-of-order execution,
- examine the limits of computing power for specific applications and architectures using the Roofline model,
- explain the common approaches and protocols for cache coherence in multiprocessor systems and demonstrate how they work with examples, and
- quantitatively evaluate different characteristics of modern computer systems through computer simulation and interpret the results.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Christian Plessl, Prof. Dr. Marco Platzner

13	**Other Notes:** *Remarks of course Advanced Computer Architecture:* **Implementation method** The course consists of a lecture and paper&pencil as well as practical exercises. The lecture is held with a beamer and blackboard. In the paper&pencil exercises, assignments are handed out and their solutions are presented and discussed in an exercise session. In the practical exercises, the effects of design decisions and optimisation options at the hardware and software level are examined and deepened on the computer with simulators of processor and memory systems using case studies. **Learning Material, Literature** • Lecture slides and exercise sheets • Exercise sheets and technical documentation for the for the computer-based exercises • Hennessey, Patterson: Computer Architecture: A Quantitative Approach (6th edition), Morgan Kaufmann, 2017. • Information about alternative and additional literature as well as teaching material on the course's website and in the lecture slides

Statistische Signale			
Statistical Signals			
Module number: M.048.210XX	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de / en	**Semester number:** 1	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.21004 Statistical Signal Processing	2L 2Ex, WS	60	120	C	60/30
b)	L.048.24014 Statistical Signal Processing	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

1 of 2 resp. Course a) or b)

3 **Admission requirements:**

None

Prerequisites of course Verarbeitung statistischer Signale:
Recommended: Basic knowledge of statistical signal description as learned in a bachelor's degree program in electrical engineering or related disciplines.

Prerequisites of course Statistical Signal Processing:
Recommended: Undergraduate courses in signal processing and probability

4 **Contents:**

Contents of the course Verarbeitung statistischer Signale:
Short description
With the course Processing of Statistical Signals, students gain an understanding of the importance of descriptive and inferential statistics for many areas of electrical engineering. They consolidate their basic knowledge of probability calculus and statistics and gain an insight into estimation and detection theory, as well as statistical time series analysis. In addition, procedures are presented with the help of which estimated values obtained from data can be evaluated with regard to statistical significance. Knowledge of detection and estimation theory, as well as time series analysis, and critical evaluation of experimental results are essential for understanding and critically applying modern signal processing techniques.
Contents

- Random experiment, axiomatic notion of probability.
- Concept of random variables, distribution function, important distributions of discrete and continuous random variables, random variable transformation.
- Maximum likelihood parameter estimation, linear estimators, quality assessment of estimators, Cramer-Rao bound.
- Bayesian estimation, (L)MMSE estimation, special case Gaussian distribution
- Stochastic processes, stationarity, ergodicity, correlation function and power density spectrum, white noise, Markov chains
- Optimal filter according to Wiener, autoregressive processes
- Maximum-a-Posteriori and Neyman-Pearson decision rule, receiver operating characteristic, statistical hypothesis tests

Contents of the course Statistical Signal Processing:
Short Description
Statistical signal processing comprises the techniques that engineers and statisticians use to draw inference from imperfect and incomplete measurements. This course covers a selection of topics from the major domains of detection, estimation, and time series analysis.
Contents
Topics that may be covered in this course include correlation analysis, linear minimum mean-squared error estimation, performance bounds for parameter estimation, Neyman-Pearson detectors, wide-sense stationary, nonstationary and cyclostationary time series, and complex-valued random signals.

5 **Learning outcomes and competences:**

Domain competence:
After attending the module, students will be able to,

- describe random variables or signals with methods of statistical signal processing
- independently perform calculations regarding reliability, hit frequency, etc.
- Design and apply estimation methods for simple parameter estimation problems.
- Construct statistical hypothesis tests and apply them to concrete problems
- Define the boundary conditions for experimental investigations in such a way that the results lead to reliable conclusions
- Compare newly obtained experimental data with existing models
- To apply a correlation or spectral analysis to time series
- To design optimal filters for given problems.

After attending this module, students will be familiar with the basic principles of statistical signal processing. They will understand how to use statistical signal processing techniques in electrical engineering and they will be able to apply them to relevant areas (such as in communications engineering). Students will develop the confidence to solve mathematical problems in analysis and design. The principles learned in this course can be applied to other fields.
Key qualifications:
Students will

- Are able to apply the methods of describing quantities and signals as random variables or random processes to a wide variety of problems in the field of electrical engineering and information technology.
- Are able to assess the power, but also the limitations of statistical methods in various applications.
- Are able to critically evaluate results of experimental investigations from various fields of application and to design experiments in such a way that their results allow reliable conclusions to be drawn.
- Are able to evaluate measurement results using modern program systems
- Are able to analyze extensive tasks in a group, break them down into subtasks and work on them in a solution-oriented manner.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a) - b)	Written or Oral Examination	120-180 min or 30-45 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik
12	**Module coordinator:** Prof. Dr. Reinhold Häb-Umbach
13	**Other Notes:** *Remarks of course Verarbeitung statistischer Signale:* **Course Homepage** [https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/statistical-signal-processing](https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/statistical-signal-processing **Methodical implementation** • lectures with predominant use of blackboard, occasionally slide presentation • Classroom exercises with exercise sheets and demonstrations on the computer • Practical exercises with Matlab, in which students independently develop and implement an experimental setup, and apply statistical analysis methods to the obtained results **Learning materials, references**. Provision of a detailed script and keyword summary slides for each lecture. Provision of exercise problems including sample solutions and example implementations in Matlab. Further literature: • N. Henze, Stochastik für Einsteiger, 8th edition, Vieweg-Teubner Verlag, 2010. • E. Hänsler, Statistical Signals — Fundamentals and Applications, 3rd edition, Springer, 2001 • S. M. Kay, Fundamentals of Statistical Signal Processing — Estimation Theory, Prentice Hall, 1993 • J. L. Melsa, D. L. Cohn, Decision and Estimation Theory, McGraw-Hill, Kogakusha, 1987. • A. Papoulis, Probability, Random Variables, and Stochastic Processes, 2nd edition, McGraw-Hill, New York, 1984. *Remarks of course Statistical Signal Processing:* **Course Homepage** `http://sst.upb.de/teaching` **Implementation** Lectures and tutorials **Teaching Material, Literature** Literature references are given in the first lecture.

Analysis and Design of Electronic Circuits			
Analysis and Design of Electronic Circuits			
Module number: M.048.90107	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.90107 Analysis and Design of Electronic Circuits	2L 2Ex, WS	60	120	C	90/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Analysis and Design of Electronic Circuits:
Recommended:
Good knowledge in differential equations, Laplace transform, Fourier transform, electrical network analysis (Kirchhoff's laws, Norton equivalent, Thevenin equivalent, transfer functions, Bode diagram etc.), semiconductor device physics (band diagram, conduction mechanisms in semiconductors, minority and majority charge carriers, n-type, p-type semiconductor, physics of pn junction, physics of MOS capacitance), semiconductor devices (physical operation and device equations of pn-diode, MOS transistor, and bipolar transistor), basic digital design (boolean algebra, truth tables, combinational logic)

4

Contents:

Contents of the course Analysis and Design of Electronic Circuits:

Short Description

The lecture gives an introduction to analysis and design of analog and digital circuits and systems. It builds on basic knowledge of electron devices (bachelor-level) and the compulsory lectures “Advanced System Theory” and “Modeling and Simulation”. The lecture presents a modern approach for analysis and design of electronic circuits and system which combines mathematical analysis and circuit simulation.

Contents

- Nonlinear, large-signal modeling of pn diode, bipolar junction transistor (BJT), and MOS transistor
- Nonlinear, large-signal analysis of circuits with diodes, BJTs, MOS transistors
- Linear modeling and one-/two-port representations of diodes, transistors, and amplifiers
- Linear small-signal analysis of BJT and MOS transistor amplifiers
- Single-transistor amplifier analysis
- Differential amplifier analysis
- Modeling and analysis of operational amplifier circuits
- CMOS logic
- Analysis and design of combinational logic circuits
- Analysis and design of sequential logic circuits
- Application examples

5

Learning outcomes and competences:

Domain competence:

The students will be able to

- describe appropriate methods for analysis and design of analog systems
- describe appropriate methods for analysis and design of digital systems
- assess the limitations of the different methods
- understand and calculate the behaviour of simple analog and digital circuits
- use a numeric simulation tool for electronic systems and circuit simulation
- describe typical components and subsystems

Key qualifications:

The lecture conveys an understanding of the interaction of different modeling techniques, mathematical analysis approaches, and numerical simulation, as well as how to apply these effectively to the design of electronic systems. The methods for analog electronic design are transferrable to the design of continuous-time, continuous-amplitude systems. The methods for digital design are transferrable to the design of discrete-time, discrete-amplitude systems.

6

Assessments:

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr.-Ing. J. Christoph Scheytt
13	**Other Notes:** *Remarks of course Analysis and Design of Electronic Circuits:* **Course Homepage** `https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/circuit-and-system-design/` **Implementation** • Lecture with Powerpoint presentation and handwritten mathematical derivations using tablet and beamer • One part of the exercises as handwritten calculation exercises using tablet and beamer • Other part of exercises as practical design tasks using using LTspice simulation **Teaching Material, Literature** Lecture slides and videos; Exercise slides. Additional literature references will be given in the first lecture • Richard C. Jaeger, Travis N. Blalock, “Microelectronic Circuit Design”, McGraw Hill, 4th edition, 2010 • Neil H. E. Weste, David Money Harris, “CMOS VLSI Design”, Addison Wesley, 4th edition, 2010

Projektgruppe			
Project Group			
Module number: M.079.01290	**Workload (h):** 540	**Credits:** 18	**Regular Cycle:** summer- / winter term
Language: en	**Semester number:** 2-3	**Duration (in sem.):** 2	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.079.07099 Project Group	PG	240	300	C	16

2 **Options within the module:**

none

3 **Admission requirements:**

The module Project Group cannot be chosen as an early performance according to §12 (4) of the General Regulations.

Prerequisites of course Projektgruppe:
Recommended Proficiencies
Depending on the topic.

4 **Contents:**

Contents of the course Projektgruppe:
In a project group, a group of usually 8-16 students works together over a period of one year (two semesters) on a research topic determined by the group organizer. Project groups introduce students to current research topics that are usually related to the group organizer's special area of interest, and the team working of the project group should be a preparation for industrial practice. Topics of project groups cover the whole range of research interests of the research groups in the Department of Computer Science.
Typically, the project group members are divided into subteams. The team selects a project group leader who controls the work of the whole team. The leader is responsible for internal communication and reporting potential issues to the group organizer. The team members meet regularly to discuss their progress with the group organizer and report on their current progress status. The team members successfully pass this module after submitting the source code and the group report, and providing the final presentation. Further constraints can be defined by the group organizer.

5 **Learning outcomes and competences:**

In project groups, participating students gain first-hand practical experience in working in a team and organizing a project; in doing so, they become prepared for daily work in their later professions. The students personally experience how to carry out extensive development processes in a team. Since the tasks are divided among the individual team members, the participating students become skilled in reporting their progress and research findings to the other group members.

Non-cognitive Skills

- Commitment
- Team work
- Learning competence
- Learning motivation
- Motivation
- Literacy (scientific)
- Self-monitoring

6 **Assessments:**

☐Final module exam (MAP) ☐Module exam (MP) ☒Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Software with documentation, presentation		75%, 25%

Im Modul Projektgruppe sind regelmäßig Berichte über den Arbeitsfortschritt zu erstellen. Außerdem ist die erfolgreiche Bearbeitung von Projekten durch die Abgabe von Software und Dokumentation nachzuweisen. Die Ergebnisse der Projektarbeiten sind in einer Präsentation vorzustellen. Es wird eine Note für die Gesamtheit der Teilleistungen vergeben. Die Softwareprojekte mit Dokumentation bilden 75% der Modulnote, das Referat bildet 25% der Modulnote.

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Progress reports or presentations		CA

Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the course achievement will be conducted.

8 **Prerequisites for participation in examinations:**

Prerequisite for the participation in the module final examination is the passing of the academic achievement on the course “Project Group”.

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4)

12	**Module coordinator:** Prof. Dr. Marco Platzner
13	**Other Notes:** *Remarks of course Projektgruppe:* **Implementation method** • Developing knowledge on the selected systematic approaches, methods and tools relevant to the research topic, usually done in an introductory seminar phase. • Logical assigning “jobs” (assigning responsibilities to the individual group members). • Discovering and promoting the participants’ special individual talents, which are either already apparent or which can be developed throughout the project - such as through seminar presentations or appropriate job assignments. • Setting up a process-oriented personnel structure, similar to the structure of an industrial design team; delegating subtasks to smaller subgroups who report their findings. • Regular progress reports made by individuals and subgroups. • Writing a highly distributed interim report and final report. **Learning Material, Literature** Depending on the topic.

Wissenschaftliches Arbeiten			
Scientific Work Style			
Module number: M.048.42941	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de	**Semester number:** 2. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.90801 Languages, Writing and Presentation Techniques		30	30	C	15
b)	Seminar (CE)	S2	30	90	C	15

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Sprachen, Schreib- und Präsentationstechnik:
None

Prerequisites of course Seminar (CE):
Recommended Proficiencies
Depending on the seminar topic.

4 **Contents:**

Contents of the course Sprachen, Schreib- und Präsentationstechnik:
Depending on their previous knowledge and interest, students choose a course from the range of courses offered by the University of Paderborn in the field of modern languages, scientific writing or presenting scientific topics.

Contents of the course Seminar (CE):
A seminar is intended for in-depth, independent familiarization with a complex scientific issue, the necessary literature research, and the presentation of the results in spoken and written form. It also helps to familiarize students with the essential mechanisms of the scientific community (conferences, reviewing principles, . . .). Seminars are offered by all lecturers; topics change from semester to semester and originate from the research area of the respective lecturer.

5 **Learning outcomes and competences:**

The goal of this module is to enable students to autonomously familiarize themselves with complex technical and scientifc material and to effectively and efficiently communicate such material in speech and writing. To this end, the module comprises a seminar on scientific topics from computer engineering and an elective class on language, technical writing, presentation techniques, etc.

- Commitment and dedication
- Cooperation competence
- learning competence
- media competence
- Writing and reading competence (scientific)

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a) - b)	Presentation	30 min	100%

7 **Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)			QP
b)			

Qualified participation in the course a)of the module according to § 39 Special Regulations. Details on the form and scope or duration will be announced by the instructor within the first three weeks of the lecture period at the latest.

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after passing the module examination (MAP) and providing proof of the qualified participation.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4)

12 **Module coordinator:**

Prof. Dr.-Ing. Katrin Temmen

13	**Other Notes:** *Remarks of course Sprachen, Schreib- und Präsentationstechnik:* Registration Note: For the course “Languages, Writing and Presentation Techniques”, please proceed as follows for pragmatic reasons: Select a course from the overall university course program matching the conditions specified in the module handbook, obtain a written confirmation of your successful participation and pass this proof on to me (letterbox next to room P1.6.09.2 or pdf-file to Katrin.Temmen@upb.de) before start of • Winter semester: by 31 March or • Summer semester: by 30 September. I will then have this registered in PAUL. Please ensure that besides your matriculation number the respective module (Bachelor v2: L.048.90802 / M.079.0116; Bachelor v3 & v3b: L.048.90802 / M.079.01209; Master v3: L.048.90801 / M.048.42941) is also mentioned on the proof of registration. Katrin Temmen *Remarks of course Seminar (CE):* **Implementation method** Seminars are based on a list of given topics from which students can make a selection. After a topic is assigned, there are usually a few appointments to discuss literature research, literature selection, presentation technique, technical writing, etc. At the same time, students begin the literature search. In constant interaction with the supervisor and the other seminar participants, a seminar paper and a presentation are developed through some milestones, which are then presented to the group and discussed. **Learning Material, Literature** Scientific publications.

3 Specialisation Area

3.1 Specialisation Area “Communication and Networks”

Specialisation Area	Communication and Networks
Modules	* Advanced Distributed Algorithms and Data Structures * Integrated Circuits for Wireless Communications * Optical Communication A * Optical Communication B * Optical Communication C * Optimal and Adaptive Filters * Optoelectronics * Fast Integrated Circuits for Wireline Communications * Topics in Signal Processing * Web Security * Wireless Communications
Catalogue advisor	Hellebrand, Sybille, Prof. Dr.
Credits ECTS	6
Learning objectives	

The modules from this specialisation area enable specialisation in the field of communication and networks.

Advanced Distributed Algorithms and Data Structures			
Advanced Distributed Algorithms and Data Structures			
Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4006	180	6	winter term

Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7012 Advanced Distributed Algorithms and Data Structures	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Advanced Distributed Algorithms and Data Structures:
Recommended Proficiencies
Algorithms and data structures, distributed algorithms and data structures

4 **Contents:**

Contents of the course Advanced Distributed Algorithms and Data Structures:
After a short introduction of the foundations of graph and network theory as well as distributed programs, the lecture presents advanced methods in the area of distributed algorithms and data structures. Topics covered in the course are access control, synchronization, consensus, information dissemination, hybrid networks, scheduling, and optimization. In addition to presenting solutions to these topics, also concrete applications will be presented.
The lecture gives an introduction to state-of-the-art advanced distributed algorithms and data structures. In addition to the presentation of the corresponding protocols, their correctness and efficienty will be shown in a rigorous way. The lecture is structured as follows:

- Introduction
- Fooundations of graph and network theory
- Access control
- Synchronization
- Consensus
- Information dissemination
- Hybrid networks
- Scheduling
- Optimization

In addition to presenting solution to these topics, also concrete applications will be presented.

5 **Learning outcomes and competences:**

Students will be able to

- understand and apply basic analytical techniques,
- explain and use basic algorithmic approaches,
- judge which effects these approaches have, and
- know the limits of using these approaches.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Christian Scheideler

13 **Other Notes:**

Remarks of course Advanced Distributed Algorithms and Data Structures:
Implementation Method
The lecture uses a blackboard and slides as well as small exercises for the students during the lecture. It will be supported by tutorial groups. Students have the opportunity in tutorial groups to work on problems in a group and to discuss solutions of the exercise sheets with the tutors.
Learning Material, Literature

- Slides of the lecture; exercise sheets
- Additional literature will be announced in the course

Integrierte Schaltungen für die drahtlose Kommunikation			
Integrated Circuits for Wireless Communications			
Module number: M.048.25017	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.25017 Integrated Circuits for Wireless Communications	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Integrierte Schaltungen für die drahtlose Kommunikation:
Recommended: Lecture Schaltungstechnik rsp. Circuit and System Design. Helpful supplement: Lecture “Wireless Communications” of Prof. Hab-Umbach.

4 **Contents:**

Contents of the course Integrierte Schaltungen für die drahtlose Kommunikation:

Short Description

Mobile communications, wireless networks, and RFID technology are application examples of wireless communications. Wireless communications has found widespread use in everyday life and will become even more important in the future. The design of electronic circuits for radio frequencies requires a good system knowledge with respect to typical transmitter and receiver architectures in wireless communications, components, and radio signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required. Goal of the lecture is to convey a methodical approach to the design of integrated circuits for wireless communications. A part of the exercises will pertain to calculation of circuit design problems another will be performed in small teams as a hands-on exercise using modern IC design software.

Contents

The lecture deals with analysis and design of radio frequency integrated circuits for wireless communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures “Schaltungstechnik” rsp. “Circuit and System Design”. The following topics will be addressed:

- Transmitter and receiver architectures for wireless communications
- System Theory Basics
  - Signals and noise
  - Modulation and demodulation
  - Transmission properties of wireless communcations systems
- Semiconductor technologies and integrated high-frequency devices
- Amplifiers (low-noise and variable-gain amplifiers)
- Mixers
- Oscillators
- Frequency synthesizer PLLs

5 **Learning outcomes and competences:**

The students will be able

- to describe architectures and circuits of wireless communication systems
- to describe and calculate fundamental signal transmission properties of wireless systems
- to apply design methods to design components of radio frequency ICs

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Oral Examination	30-45 min	100%

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr.-Ing. J. Christoph Scheytt
13	**Other Notes:** *Remarks of course Integrierte Schaltungen für die drahtlose Kommunikation:* **Course Homepage** `https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/integrierte-schaltungen-fuer-die-drahtlose-kommunikation/` **Implementation** • Lecture with Powerpoint presentation and handwritten mathematical derivations using tablet and beamer • Exercises partly as handwritten calculation exercises using tablet and beamer and partly as practical IC design exercises using IC design software **Teaching Material, Literature** Lecture slides and videos as well as exercise slides will be made available. • Behzad Razavi “RF Microelectronics”, Prentice Hall, 2011 • Thomas Lee “The Design of CMOS Radio-Frequency Integrated Circuits”, Cambridge University Press 2003

Optical Communication A			
Optical Communication A			
Module number: M.048.92019	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92019 Optical Communication A	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Communication A:
None

4 **Contents:**

Contents of the course Optical Communication A:
Short Description
The lecture Optical Communication A gives basic knowledge in Optical Communication and the components used in this field.
Contents
Maxwell's equations, wave propagation, polarization, dielectric slab and cylindrical waveguides, dispersion, laser, photodiodes, optical amplifiers, modulation, signal formats, optical receivers, noise, regenerators, wavelength division multiplex. Here the most important knowledge is taught.

5 **Learning outcomes and competences:**

Professional Competence
After attending the course, the students will be able, in the taught subjects, to

- describe, model and apply the function of components, systems and effects of optical communications and
- apply knowledge of optoelectronics

(Soft) Skills
The students

- are able to apply the knowledge and skills to a wide range of disciplines,
- are able to make use of a methodical procedure when undertaking systematic analysis and
- are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Reinhold Noé

13 **Other Notes:**

Remarks of course Optical Communication A:
Course Homepage
`http://ont.upb.de`
Teaching Material, Literature
Scripts, exercise sheets and advanced literature (excerpt):

- R. Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7
- Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag (modernes Nachschlagewerk) 2002
- D. As, Univ. Paderborn, Vorlesung Optoelektronik
- W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik
- G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991, (umfassend, viele Zwischenschritte fehlen)
- K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992
- H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter)
- Yariv, Optical Electronics, Holt, 1984 (und weitere Werke, sehr physikalisch, kaum Nachrichtentechnik)
- R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

Optical Communication B			
Optical Communication B			
Module number: M.048.92020	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92020 Optical Communication B	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Communication B:
None

4 **Contents:**

Contents of the course Optical Communication B:
Short Description
The lecture Optical Communication B gives some knowledge about mode coupling in Optical Communication and explains the function of many optical components.
Contents
Mode Coupling: Polarization mode dispersion, moden orthogonality, constant and periodic, co- and counterdirectional mode coupling, profiles of differential group delay, electrooptic effect. The function of many passive and active optical elements is thereby explained, among others amplitude and phase modulators, broadband and wavelength-selective couplers, Bragg gratings, polarization-maintaining fibers, polarization transformers, equalizers for polarization mode dispersion and chromatic dispersion.

<table>
<tr><td>5</td><td>Learning outcomes and competences:

Professional Competence
After attending the course, the students will be able, in the taught subjects, to
• describe, model and apply the function of components, systems and effects of optical communications and
• apply knowledge of optoelectronics

(Soft) Skills
The students
• are able to apply the knowledge and skills to a wide range of disciplines,
• are able to make use of a methodical procedure when undertaking systematic analysis and
• are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master’s Program Electrical Systems Engineering (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Reinhold Noé</td></tr>
</table>

13 **Other Notes:**

Remarks of course Optical Communication B:
Course Homepage
`http://ont.upb.de`
Teaching Material, Literature
Scripts, exercise sheets and advanced literature (excerpt):

- Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7
- Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag (modernes Nachschlagewerk) 2002
- D. As, Univ. Paderborn, Vorlesung Optoelektronik
- W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik
- G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991, (umfassend, viele Zwischenschritte fehlen)
- K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992
- H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter)
- Yariv, Optical Electronics, Holt, 1984 (und weitere Werke, sehr physikalisch, kaum Nachrichtentechnik)
- R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

Optical Communication C			
Optical Communication C			
Module number: M.048.92021	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92021 Optical Communication C	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Communication C:
None

4 **Contents:**

Contents of the course Optical Communication C:
Short Description
The lecture Optical Communication C gives knowledge in various optical modulation and demodulation techniques.
Contents
Modulation Formats: Data transmission by differential binary and quaternary phase shift keying in the presence of optical amplifiers, polarization division multiplex, coherent optical data transmission, synchronous and asynchronous demodulation, coherent baseband receivers, polarization diversity, electronic compensators of optical distortions like electronic polarization control and electronic compensation of polarization mode dispersion and chromatic dispersion, phase noise, other modulation formats. Advanced modulation formats are an important possibility for the upgrading of high-performance optical information transmission systems.

5 **Learning outcomes and competences:**

Professional Competence
After attending the course, the students will be able, in the taught subjects, to

- describe, model and apply the function of components, systems and effects of optical communications and
- apply knowledge of optoelectronics

(Soft) Skills
The students

- are able to apply the knowledge and skills to a wide range of disciplines,
- are able to make use of a methodical procedure when undertaking systematic analysis and
- are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Reinhold Noé

13	**Other Notes:** *Remarks of course Optical Communication C:* **Teaching Material, Literature** Scripts, exercise sheets and advanced literature (excerpt): • Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7 • Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag (modernes Nachschlagewerk) 2002 • D. As, Univ. Paderborn, Vorlesung Optoelektronik • W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik • G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991, (umfassend, viele Zwischenschritte fehlen) • K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992 • H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter) • Yariv, Optical Electronics, Holt, 1984 (und weitere Werke, sehr physikalisch, kaum Nachrichtentechnik) • R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

Optimale und Adaptive Filter			
Optimal and Adaptive Filters			
Module number: M.048.24010	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.24010 Optimal and Adaptive Filters	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optimale und Adaptive Filter:
Recommended: Prior knowledge from the modules Higher Mathematics and Digital Signal Processing.

4 **Contents:**

Contents of the course Optimale und Adaptive Filter:

Short Description

The course “Optimal and adaptive filters” gives an introduction to the basic techniques and theories of adaptive filters. Based upon the basics of estimation theory optimal filters are discussed. Subsequently the topics Wiener filter theory, deterministic optimization under constraints and stochastic gradient methods are regarded. Concluding the Least Squares approach for solving filter tasks and the Kalman filter are introduced. The latter is regarded as a brief introduction to state based filters.

Contents

- Classic parameter estimation
- Estimators
- MMSE-Estimation
- Linear estimators
- Orthogonality principle
- Evaluation of estimators
- Wiener filter
- Wiener-Hopf equation
- AR- and MA processes
- Linear prediction
- Iterative optimization methods
- Gradient ascent/descent
- Newton method
- Linear adaptive filters
- LMS algorithm
- Least-Squares method
- Blockwise and recursive adaptiv filters
- Realization aspects
- Statemodel based filters
- Kalman filter
- Applications
- System identification
- Channel estimation and equalization
- Multi-channel speech signal processing
- Noise and interference suppression

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the students will be able to

- analyze task on the field of adaptive filters and to formulate requirements mathematically,
- develop filter using cost functions and
- implement selected adaptive filters in the frequency or time domain.

Key qualifications:
The students

- are able to check theoretical results using practical realizations,
- are able to undertake theoretical approaches a systematic analysis using methodical procedures and
- are, due to the precise treatment of the contents, in a position to continue their learning themselves.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12 **Module coordinator:**

Dr.-Ing. Jörg Schmalenströer

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Other Notes:

Remarks of course Optimale und Adaptive Filter:
Course Homepage
`https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/optimal-and-adaptive-filter`
Implementation

- Lectures using the blackboard and presentations,
- Alternating theoretical and practical exercises classes with exercise sheets and computer and
- Demonstration of real technical systems in the lecture hall.

Teaching Material, Literature
Allocation of a script; information on textbooks; matlab scripts

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</table>

Optoelectronics			
Optoelectronics			
Module number: M.048.26011	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.26011 Optoelectronics	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optoelectronics:
None

4 **Contents:**

Contents of the course Optoelectronics:

Short description

The lecture Optoelectronics covers the fundamental aspects of optoelectronic devices, starting with semiconductor materials and their interaction with light and photons, to the electronic aspects of the components, and finally to the use of quantum mechanical effects to optimise modern components for their respective areas of application, such as in lighting systems, renewable energy, broadband optical communication systems or in medical technology.

Contents

In the first part of the lecture, the basics of semiconductors (lattice structure, band structure, direct-indirect semiconductors, doping, degenerate and non-degenerate semiconductors, heterostructures, quantum effects in low-dimensional semiconductors) are recapitulated. The elementary interactions between light and semiconductors (absorption, stimulated emission, spontaneous emission) and the electronic aspects of the components (p-n junction, heterojunctions) are then covered. Finally, the most important devices such as solar cells, photodiodes, light-emitting diodes and semiconductor lasers are discussed in detail and their most important parameters and optimisation strategies are explained.

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the students will be able to

- explain the basic physical properties of optoelectronic semiconductor devices based on classical and fundamental quantum mechanical descriptions,
- to describe the main concepts of optoelectronic semiconductor devices (photodiodes, solar cells, light emitting diodes, semiconductor lasers),
- categorize different device designs according to their application requirements.

Key qualifications:
The students

- can use of methodic knowledge for systematic problem analysis for a wide range of disciplines,
- will be in position to familiarise themselves independently with new generations of semiconductor devices, thanks to the comprehensive fundamental training received,
- get familiar to rate-equation models to simulate steady-state and dynamic characteristics in coupled systems,
- and gain foreign language competences related to the field.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12	**Module coordinator:** Prof. Dr.-Ing. Nils Christopher Gerhardt
13	**Other Notes:** **Module Homepage** to be announced at the start of the lecture **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Lecture notes and handouts for the tutorial; literature references will be given in the first lecture

Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation			
Fast Integrated Circuits for Wireline Communications			
Module number: M.048.25019	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.25019 Fast Integrated Circuits for Wireline Communications	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:
Recommended: Module “Schaltungstechnik” of the Bachelor Electrical Engineering or module “Circuit and System Design” of the Master “Electrical Systems Engineering” or comparable modules / lectures

4	**Contents:** *Contents of the course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:* **Short Description** Nowadays commercial fiber-optic communication systems reach very high data rates of 100 Gb/s per optical channel and several Tb/s in a single fiber. In a similar way very high data rates of more than 10 Gb/s occur at a single package pin of electronic chips. These signals are to be transmitted over printed circuit boards and inexpensive serial cables. In the future the progress of CMOS technology and communication technology will push speed of fiber-optic and wire-line communication continuously to ever higher data rates. The design of electronic circuits for high bandwidth rsp. data rates requires a good system knowledge with respect to typical transmitter and receiver architectures, components, and signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required. Goal of the lecture is to enable the student to utilize a methodological approach for the design of fast integrated electronic circuits for digital wired communications. A part of the exercises will be carried out using modern industry-standard IC design software. **Contents** The lecture deals with analysis and design of fast integrated electronic circuits for digital broadband communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures “Schaltungstechnik” rsp. “Circuit and System Design”. The lecture deals with: • Transmitter and receiver architectures for fiber-optic communications • Transmitter and receiver architectrues for chip-to-chip communications • System design • Semiconductor technology and integrated high-frequency devices • Broadband amplifiers • Current-mode logic • Transmitter and receiver circuits • PLLs for frequency synthesis and clock recovery • Measurement methods
5	**Learning outcomes and competences:** **Domain competence:** The student will be able to: • describe and analyze transmitter and receiver architectures for broadband communication links • understand and describe semiconductor technologies and integrated high-frequency devices for broadband circuits • to analyze circuit design techniques for transmitter and receiver circuits and describe ways to optimize them • to describe circuits in PLL technique for frequency synthesis and clock recovery • to describe measurement methods **Key qualifications:** The students will learn how different interdisciplinary scientific domains and their methods - like mathematical signal and system analysis, non-linear and linear circuit analysis, semiconductor physics, semiconductor devices and high-frequency engineering - are applied together for the development of communications application.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Oral Examination	30-45 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr.-Ing. J. Christoph Scheytt
13	**Other Notes:** *Remarks of course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:* **Course Homepage** `https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/fast-integrated-circuits-for-wireline-communications/` **Implementation** Lecture with Exercises (including computer-aided design using electronic design software) **Teaching Material, Literature** Handouts and literature references will be given in the lecture. • E. Säckinger, “Broadband Circuits for Optical Fiber Communication”, Wiley, 2005 • B. Razavi, “Design of Integrated Circuits for Optical Communications”, McGraw-Hill, 2003 **Comments** As part of the lecture a 2-day excursion to IHP Leibnizinstitute for High-Performance Microelectronics in Frankfurt (Oder) is offered which includes the visit of a modern chip fabrication facility (participation in the excursion is voluntary).

<table>
<tr><th colspan="4">Topics in Signal Processing</th></tr>
<tr><td colspan="4">Topics in Signal Processing</td></tr>
<tr><td>Module number:
M.048.92014</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
winter term</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
</table>

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92014 Topics in Signal Processing	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Topics in Signal Processing:
Recommended: Signal and system theory, at least a basic understanding of probability and linear algebra

4 **Contents:**

Contents of the course Topics in Signal Processing:
Short Description
This course covers a selection of current topics in signal processing. One part of this course will follow a regular lecture format, while the other part will require active student participation.
Contents
This course will first review relevant aspects of linear algebra and probability theory. Then students will learn how to read, analyze, and present recent papers from the signal processing literature.

5 **Learning outcomes and competences:**

In this course, students will familiarize themselves with some current research topics in signal processing. They will learn to read and understand scientific publications and to critically evaluate results. Students will develop confidence in their ability to solve mathematical problems of analysis and design. They will be able to apply the principles they have learnt in this course to other areas.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Peter Schreier
13	**Other Notes:** *Remarks of course Topics in Signal Processing:* **Course Homepage** `http://sst.uni-paderborn.de/teaching/courses/` **Implementation** Lectures and tutorials with active student participation, student presentations **Teaching Material, Literature** References will be given in the first lecture.

<table>
<tr><th colspan="5">Web Security</th></tr>
<tr><td colspan="5">Web Security</td></tr>
<tr><td colspan="2">Module number:
M.079.4073</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
summer term</td></tr>
<tr><td colspan="2">Language:
en</td><td>Semester number:
1-3</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
P</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>2024.7049
Web Security</td><td>L3
Ex2</td><td>75</td><td>105</td><td>C</td><td>70/35</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
none</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
none
<i>Prerequisites of course Web Security:</i>
Recommended Proficiencies
Knowledge in programming, IT security and basic knowledge in cryptography</td></tr>
</table>

4 **Contents:**

Contents of the course Web Security:
Modern web applications and web services usually consist of multiple layers. They are based on different (often complex) technologies that are constantly being developed. Their complexity is often the reason for new types of attacks that can be observed on the web every day.
In this lecture, we will focus on the most important technologies and learn what you have to consider while securing your web applications. We will introduce prominent and widespread attacks and show how to prevent them. These range from typical attacks from the OWASP Top 10 list, such as XSS or SQL Injection, to attacks on web services and Single Sign-On standards (e.g., on SAML and OpenID Connect). Based on many cases, we will learn what is important in the design and implementation of secure web applications.
The course includes the following contents:

- Introduction to web technologies
- Web Attacks
  - Cross-Site Scripting (XSS)
  - Cross-Site Request Forgery (CSRF)
  - Clickjacking
  - SQL injection
- XML and SAML
  - Attacks on XML parsers
  - Attacks on XML Signature
- JSON and OpenID Connect (OIDC)
  - Attacks on OIDC

5 **Learning outcomes and competences:**

Students will be able to

- Understand security concepts behind web applications
- Understand and prevent common attacks on web applications
- Carry out practical analyses of web applications with common tools
- Identify and assess implementation errors and security problems in web applications

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** <table><tr><th>zu</th><th>Type of achievement</th><th>Duration or Scope</th><th>SL / QT</th></tr><tr><td>a)</td><td>Assignments, course paper or progress reports</td><td></td><td>CA</td></tr></table>
8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr.-Ing. Juraj Somorovsky
13	**Other Notes:** *Remarks of course Web Security:* **Implementation method:** The topics are conveyed through lecture presentations. They are further deepened through individual practical tasks. **Learning Material, Literature:** • Lecture slides and exercise sheets • Scientific literature • Additional literature will be announced in the course.

Wireless Communications			
Wireless Communications			
Module number: M.048.92035	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92035 Wireless Communications	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Wireless Communications:
Recommended: Some basic knowledge in digital communication systems.

4 **Contents:**

Contents of the course Wireless Communications:
The course provides students with an insight into the techniques for reliable communication via time and/or frequency selective radio channels. To this end, the physical and statistical modeling of the radio channel is first presented, which forms the basis for understanding the transmission methods adapted to these channel conditions. Then, the main transmission and reception principles are presented, in particular the different diversity schemes:

- Time diversity: maximum ratio combiner, error rate calculation for coherent and incoherent reception, interleaving.
- Antenna diversity: SIMO, MISO and MIMO techniques
- Frequency diversity for frequency selective channels: Single-carrier techniques with sequence detection, band-spreading techniques, multicarrier transmission.

Emphasis will be placed on an illustrative derivation of the receiver principles as operations in a linear vector space. In addition, an insight into current cellular radio communication systems is given.
Table of contents

- Pulse amplitude modulation and orthogonal multi-pulse modulation
- Optimal detection
- Channel models for mobile radio
- Treatment of intersymbol interference
- Error rate on frequency nonselective Rayleigh Fading channel
- Diversity schemes: time, space, and frequency diversity
- Channel coding
- Cellular systems

5 **Learning outcomes and competences:**

Domain competence:
After completion of the course students will be able to

- Develop a discrete-time statistical channel model for a given physical description of a wireless communication channel
- Explain the techniques and algorithms used in the Physical Layer of a wireless communication system
- Understand the fundamental design options and decisions taken to realize reliable communication over time variant and frequency selective or nonselective fading channel
- Appreciate and categorize the techniques used in modern cellular communication systems to realize reliable communication
- Trade off the advantages and disadvantages of different transmission techniques with respect to bandwidth and power efficiency as well as number of users to be served
- Select and design an appropriate transmission technique for a wireless channel
- Simulate and analyze simple communication systems using modern software tools

Key qualifications:
The students

- Can transfer and apply the concept of linear vector spaces to signal processing tasks other than for wireless communications
- Can apply the skills about the generation of data, simulation of systems and analysis of experimental results using modern software tools, that have been acquired in this course, to other disciplines
- Can work cooperatively in a team and subdivide an overall task into manageable subtasks and work packages

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Häb-Umbach
13	**Other Notes:** *Remarks of course Wireless Communications:* **Course Homepage** `https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/wireless-communications` Course script and summary slides are provided to the students. Exercises and solutions to exercises, as well as sample implementations of algorithms are provided to the students • Häb-Umbach, Reinhold: Wireless Communications (Lecture notes) • D. Tse: Fundamentals of Wireless Communications, Cambridge University Press, 2006 • K.D. Kammeyer: Nachrichtenuübertragung, Teubner, 2004 • P. Höher: Grundlagen der digitalen Informationsübertragung, Springer/Vieweg 2013

3.2 Specialisation Area “Computer Systems”

Specialisation Area	Computer Systems
Modules	* Algorithms and Tools for Test and Diagnosis of Systems on a Chip * Introduction to Quantum Computation * Reconfigurable Computing * VLSI Testing
Catalogue advisor	Hellebrand, Sybille, Prof. Dr.
Credits ECTS	6
Learning objectives	

The modules from this specialisation area enable specialisation in the field of computer systems. The focus is on the analysis and evaluation of computer architectures, systematic methods for the design and optimisation of computer systems, in particular the interaction of hardware and software, as well as programming models and methods for the parallel and specialised computer architectures that are gaining strongly in importance.

Algorithms and Tools for Test and Diagnosis of Systems on a Chip			
Algorithms and Tools for Test and Diagnosis of Systems on a Chip			
Module number: M.048.92007	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer- / winter term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92007 Algorithms and Tools for Test and Diagnosis of Systems on a Chip	2L 2Ex, WS+SS	60	120	C	30/30

2 **Options within the module:**

None

3

Admission requirements:

None

Prerequisites of course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Recommended: VLSI Testing, (Introduction to Algorithms)

4

Contents:

Contents of the course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Short Description
The course "Algorithms and Tools for Test and Diagnosis of Systems on Chip" deals with advanced topics in test and diagnosis of integrated systems. The focus is on algorithms and tools for computer-aided preparation and application of test and diagnosis procedures.
** Contents**
Topics include but are not restricted to:

- Advanced techniques for built-in self-test and embedded test
- Built-in diagnosis
- Test of robust and self-adaptive systems
- Adaptive Testing

5

Learning outcomes and competences:

Domain competence:
After attending the course, the students will be able

- to describe recent approaches in test and diagnosis,
- to explain and apply the underlying models and algorithms,
- to explain the specific challenges of nanoscale integration and evaluate test strategies accordingly.

Key qualifications:
The students are able

- to apply their basic knowledge for studying and understanding new approaches from the state of the art literature,
- to present the new contents in a conference style presentation, and
- to describe the new contents in a scientific manuscript.

6

Assessments:

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7

Study Achievement:

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Sybille Hellebrand
13	**Other Notes:** *Remarks of course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:* **Module Homepage** `http://ei.uni-paderborn.de/en/electrical-engineering/date/teaching/electrical-engineering/overview` **Implementation** • Lecture based on slide presentation, extensions on blackboard • Self-study on recent approaches based on recent conference and journal publications • Oral presentation • Manuscript **Teaching Material, Literature** • Lecture slides • Additional material can be found in panda • Michael L. Bushnell, Vishwani D. Agrawal, „Essentials of Electronic Testing for Digital, Memory, and Mixed-Signal VLSI Circuits," Kluwer Academic Publishers,2000 • Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, „VLSI Test Principles and Architectures: Design for Testability," Morgan Kaufmann Series in Systems on Silicon, ISBN: 0123705975 • Artikel aus Fachzeitschriften und Konferenzbänden / Articles from Journals and Conference Proceedings (e.g. IEEE Transactions on Computers, IEEE Transactions on CAD of Integrated Circuits and Systems, IEEE International Test Conference, etc.)

<table>
<tr><th colspan="5">Introduction to Quantum Computation</th></tr>
<tr><td colspan="5">Introduction to Quantum Computation</td></tr>
<tr><td colspan="2">Module number:
M.079.4059</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
winter term</td></tr>
<tr><td colspan="2">Language:
en</td><td>Semester number:
1-3</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
P</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>2024.7044
Introduction to Quantum Computation</td><td>L3
Ex2</td><td>75</td><td>105</td><td>C</td><td>70/35</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
none</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
none
<i>Prerequisites of course Introduction to Quantum Computation:</i>
Recommended Proficiencies
Linear Algebra, algorithms</td></tr>
<tr><td>4</td><td colspan="4">Contents:
<i>Contents of the course Introduction to Quantum Computation:</i>
This lecture introduces the fundamental concepts of quantum computation and information from a computer science perspective. This includes an introduction to quantum mechanics, quantum entanglement, quantum algorithms, quantum error correction, and quantum information theory.
• Quantum mechanics
• Quantum entanglement
• Quantum algorithms
• Quantum error correction
• Quantum information</td></tr>
<tr><td>5</td><td colspan="4">Learning outcomes and competences:
Students are able to:
• Describe and apply the postulates of quantum mechanics
• Understand the use of entanglement as a resource
• Design and analyze fundamental quantum algorithms
• Apply the theory of error-correcting codes
• Understand and apply basic quantum information theory concepts such as entropy</td></tr>
</table>

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Sevag Gharibian

13 **Other Notes:**

Remarks of course Introduction to Quantum Computation:
Implementation method
Slides and blackboard writing. All important concepts and techniques are further deepened with examples in exercises.
Learning Material, Literature

- Michael A. Nielsen, Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press
- Lecture slides, exercises

Reconfigurable Computing			
Reconfigurable Computing			
Module number: M.079.4043	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7034 Reconfigurable Computing	L2 Ex3	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Reconfigurable Computing:
Recommended Proficiencies
Knowledge of the Bachelor-level courses Digital Design, Programming, and Data Structures and Algorithms are beneficial.

4 **Contents:**

Contents of the course Reconfigurable Computing:
The course Reconfigurable Computing introduces into the field of computing with reprogrammable hardware structures. Computing systems built from reprogrammable hardware structures do not rely on a fixed hardware, but adapt their hardware architecture to the application under execution. The field was formed in the early 1990s when Field-programmable Gate Arrays (FPGAs) became commercially available that were powerful enough to be used for computing. Today, FPGA-based high-performance systems have outperformed state-of-the-art computers for many problems including database search, genomic sequence scanning, and cryptography. In embedded systems, FPGAs accelerate system functions, reduce system cost and energy consumption, and enable hardware-on-demand functionality. The course covers the following topics:

- Introduction to reconfigurable computing
- Evolution of programmable hardware devices
- FPGA architectures
- Computer-aided design for FPGAs
- High-level languages for programming FPGAs
- Application domains for FPGAs
- Comparison of devices, technologies, and reconfigurable systems

5 **Learning outcomes and competences:**

Students will be able to

- compare different reprogrammable hardware devices and describe their historical development,
- name the design steps and problems when designing with FPGAs,
- analyse algorithms for the design steps and apply them to examples,
- compare and evaluate current approaches to programming FPGAs,
- justify the suitability of different reprogrammable hardware components for different areas of application, and
- implement functions of medium complexity with modern FPGA design tools.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Marco Platzner

13 **Other Notes:**

Remarks of course Reconfigurable Computing:

Implementation Method

The course consists of a lecture, and pencil&paper as well as practical exercises. The lecture is held with a beamer and blackboard. In the pencil&paper exercises, problems are handed out and their solutions are presented and discussed in a practice session. In addition, quizzes are offered for self-assessments. In the practical exercises, a tutorial on the design with FPGAs is carried out and then tasks are handed out, which are implemented as design or programming examples in groups of one to three participants.

Learning Material, Literature

- Lecture slides, assignment sheets for paper&pencil exercises, quizzes
- Tutorial, assignment sheets for design and programming examples, technical documentation
- Selected scientific articles
- Additional literature will be announced in the course.

VLSI-Testing

VLSI-Testing

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92027	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92027 VLSI Testing	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course VLSI Testing:
Recommended: Digital Design

4 **Contents:**

Contents of the course VLSI Testing:
Short Description
The course “VLSI Testing” focuses on techniques for detecting hardware defects in microelectronic circuits. Algorithms for test data generation and test response evaluation as well as hardware structures for design for test (DFT) and on-chip test implementation (BIST) are presented.
Contents
In detail the following topics are covered:

- Fault models
- Testability measures and design for test (DFT)
- Logic and fault simulation
- Automatic test pattern generation (ATPG)
- Built-in self-test (BIST), in particular test data compression and test response compaction
- Memory test

5	**Learning outcomes and competences:** **Domain competence:** After attending the course, the students will be able • to describe fault models, DFT techniques, and test tools, • to explain and apply the underlying models and algorithms for fault simulation and test generation, • to analyze systems with respect to their testability and to derive appropriate test strategies. **Key qualifications:** The students • are able to apply the practiced strategies for problem solving across varying disciplines, • have experience in presenting their solutions to their fellow students, and • know how to improve their competences by private study.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4, Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Sybille Hellebrand

Assessments (6):

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

13 **Other Notes:**

Remarks of course VLSI Testing:
Course Homepage
`https://ei.uni-paderborn.de/en/electrical-engineering/date/teaching/electrical-engineering/overview`
Implementation

- Lecture based on slide presentation, extensions on blackboard
- Exercises in small groups based on exercise sheets with students presenting their own solutions
- Hands-on exercises using various software tools

Teaching Material, Literature
Additional material can be found in panda

- Michael L. Bushnell, Vishwani D. Agrawal, „Essentials of Electronic Testing for Digital, Memory, and Mixed-Signal VLSI Circuits,“Boston, Dordrecht, London: Kluwer Academic Publishers, 2000
- Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, „VLSI Test Principles and Architectures: Design for Testability,“ Morgan Kaufmann Series in Systems on Silicon, ISBN: 0123705975

3.3 Specialisation Area “Control and Automation”

Specialisation Area	Control and Automation
Modules	* Advanced Control * Advanced System Theory * Advanced Topics in Robotics * Coupled Fields * Controlled AC Drives * Nonlinear control of autonomous and robotic systems * Optimization-Based Control Methods * Reinforcement Learning * Robotics * Ultrasonic measurement technology * Environmental monitoring and measuring technologies
Catalogue advisor	Hellebrand, Sybille, Prof. Dr.
Credits ECTS	6
Learning objectives	

The modules from this specialisation area enable specialisation in the field of control and automation technology.

Advanced Control			
Advanced Control			
Module number: M.048.92037	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92037 Advanced Control	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced Control :
Recommended: Undergraduate-level systems theory and automatic control

4 **Contents:**

Contents of the course Advanced Control :
Short Description
This course builds on undergraduate-level systems theory and automatic control courses and focuses on the design of discrete-time control systems, using transfer function and state-space methods. The course is primarily intended to serve engineering students, but can also be useful to students in physics and other natural sciences.
Contents

- Discretization of dynamical systems
- Multivariable PI control
- Actuator constraints and anti-windup mechanism
- Optimal linear quadratic estimation
- Optimal linear quadratic control
- Basics of model predictive control for constrained systems

5 **Learning outcomes and competences:**

Domain competence:
After attending this course, students will be able to

- study the dynamics of feedback systems
- design appropriate control systems
- utilize engineering software tools to realize and test control designs

Key qualifications:
Students learn

- to use systematic analysis and synthesis methods that can be used in a variety of disciplines, both in engineering and natural sciences
- precise methods based on abstractions that can be used to further independent learning

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Erdal Kayacan</td></tr>
<tr><td>13</td><td>Other Notes:
<i>Remarks of course Advanced Control :</i>
Course Homepage
<code>https://en.ei.uni-paderborn.de/rat</code>
Teaching Material, Literature
Book and general literature recommendations will be made during the active course time.</td></tr>
</table>

Advanced System Theory

Advanced System Theory

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92001	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1. Semester	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92001 Advanced System Theory	2L 2Ex, WS	60	120	C	60/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced System Theory:
Recommended:
Prerequisites are a basic understanding of differential equations, linear algebra, and Laplace transforms, as they are covered in a typical undergraduate course on system theory.

4 **Contents:**

Contents of the course Advanced System Theory:
Short Description
Building on an undergraduate system theory course, this course studies the dynamical behavior of linear systems with greater mathematical rigor. The course is primarily intended to serve students in engineering, but it can also be useful to students in physics and other natural sciences.
Contents

- System models and differential equations
- State-space and I/O descriptions
- Relations between internal and external descriptions
- Response of continuous- and discrete-time systems
- Stability, controllability, observability
- State-space realizations of external descriptions
- Feedback systems

5	**Learning outcomes and competences:** After attending this course, students will be familiar with the most important concepts and results in linear system theory. Students will develop confidence in their ability to solve mathematical problems of analysis and design. Many of their timeless insights and intuitions about the dynamical behavior of systems will be drawn from this course. This course presents material broad enough so that students will have a clear understanding of the dynamical behavior of linear systems, including their power and limitations. This will allow students to apply the theory to other fields.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Erdal Kayacan
13	**Other Notes:** *Remarks of course Advanced System Theory:* **Course Homepage** `https://en.ei.uni-paderborn.de/rat` **Implementation** Lectures and exercises (including some computer simulations) Panda course for communication and material distribution **Teaching Material, Literature** Handouts and exercise / tutorial questions; literature references will be given in the first lecture

Advanced Topics in Robotics

Advanced Topics in Robotics

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92006	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92006 Advanced Topics in Robotics	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced Topics in Robotics:
None

4 **Contents:**

Contents of the course Advanced Topics in Robotics:
Short Description
The course Advanced Topics in Robotics is based on the course Robotics. The students are introduced to current research topics in the field of autonomous and teleoperated mobile robots to solve interdisciplinary issues. The challenges encountered in developing intelligent mobile systems are analyzed and current solutions presented.
Contents

- Architectures of robot systems
- Middleware for hardware abstraction
- Device drivers and libraries
- Visualization
- Local navigation processes (collision avoidance)
- Global navigation processes (pathfinding)
- Navigation and self-localization methods (SLAM)
- Fundamentals of task planning

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Domain competence:
The students
are able to name and analyze the basic robot architectures for mobile robots,
have a good command of the methods for the navigation and control of mobile robots and
are able to implement, test and apply them.
Key qualifications:
The students have a good command of programming in the C language</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Bärbel Mertsching</td></tr>
</table>

13 **Other Notes:**

Remarks of course Advanced Topics in Robotics:

ATTENTION - IMPORTANT NOTICE
The course doesn’t take place in winter term 2024/25. Please see the notice boards of the group.

Course Homepage
`http://getwww.uni-paderborn.de/teaching/atir`
Implementation

- The theoretical and methodical fundamentals will be introduced during the lecture.
- The methods presented will be practiced during the subsequent exercise / lab part.
- Finally, the participants will implement, test, and apply simple algorithms.
- The necessary programming skills will be taught during the practical, this is explicitly not considered a programming course.

Teaching Material, Literature
Allocation of lecture notes; information on textbooks stocked in the textbook collection will be announced later.

- Mertsching, Bärbel: Robotics (lecture notes)
- McKerrow, Phillip J.: Introduction to Robotics. Addison-Wesley, 1991
- Siegwart, Roland; Nourbakhsh, Illah R. and Scaramuzza, David: Introduction to Autonomous Mobile Robots. The MIT Press, 2011, ISBN-13: 978-0262015356

Gekoppelte Felder

Coupled Fields

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.27028	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.27028 Coupled Fields	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Gekoppelte Felder:
Recommended: Basic knowledge from the area of classical field theory, for example from the modules “Field Theory”, “Electromagnetic Waves” and “Theoretical Electrical Engineering”.

4 **Contents:**

Contents of the course Gekoppelte Felder:
The focus of the course Coupled Fields is the classical field theory of interacting electromagnetic, thermal and mechanical phenomena as well as their application in sensors and actuators. After an introduction to the mathematical description of the individual fields, the following topics are covered:

- Electromechanical coupling based on examples in piezoelectricity, electrostriction and magnetostriction.
- Thermomechanical coupling such as thermoelasticity and lossy acoustic waves.
- Thermoelectric coupling, for example pyroelectricity.
- Phenomena with electromagnetic-thermal-mechanical coupling such as the photoacoustic effect. In addition to the description of the effects, analogies as well as similarities and differences are considered and aspects of numerical simulation are discussed.

5	**Learning outcomes and competences:** After attending the course, students will be able to • describe the discussed physical effects phenomenologically and with differential equations. • interpret the results of numerical simulations of coupled fields and check them for plausibility. • select suitable components for sensor and actuator applications of coupled fields. • infer an acting physical effect from observations.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the examination will be conducted.

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Dr.-Ing. Leander Claes

13	**Other Notes:** **Module Homepage** `https://emt.upb.de` **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Lecture slides and exercises will be provided. Additional literature references will be given throughout the course.

Geregelte Drehstromantriebe			
Controlled AC Drives			
Module number: M.048.27013	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.27013 Controlled AC Drives	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Geregelte Drehstromantriebe:
Recommended: It is strongly recommended that the students should have already finished a Bachelor course on the basics of electrical drives.

4 **Contents:**

Contents of the course Geregelte Drehstromantriebe:
Short Description
The course introduces the principle of flux-oriented control of three-phase AC motors, which is today's standard of electrical drives in industry. Unlike the course of the bachelor's program focus is put on the dynamics behavior and on the control structures. As most important examples, the permanent magnet synchronous motor and the induction motor are treated.
Contents

- AC drives: Synchronous and induction motor (structure, basic physical effects, modeling, equivalent circuit diagrams, characteristic curves, operation areas)
- Speed and torque control
- Space vector theory (fundamental wave, coordinate transformation)
- Principles of flux-oriented control
- Closed-loop control of current, torque and speed, design methods
- Direct Torque Control (DTC)
- Observers
- Applications in industry, road and rail vehicles

5	**Learning outcomes and competences:** **Domain competence:** • The students will understand the most important types of AC drives, their properties and should be able to select and to design such drives by themselves. **Key qualifications:** The students learn • to transfer the learned skills also to other disciplines, • extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises • learn strategies to acquire knowledge from literature and internet.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Dr.-Ing. Frank Schafmeister

13	**Other Notes:** *Remarks of course Geregelte Drehstromantriebe:* --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place until further notice. Final Exam: in winter termin 2024/25! --- **Course Homepage** `http://ei.uni-paderborn.de/lea/` **Implementation** Parts of the course are organized as computer-based exercises. Teaching materials: Lecture notes. Other literature will be given in the lecture

Nonlinear control of autonomous and robotic systems

Nonlinear control of autonomous and robotic systems

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.27032	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.27032 Nonlinear control of autonomous and robotic systems	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Nonlinear control of autonomous and robotic systems:
None

4 **Contents:**

5 **Learning outcomes and competences:**

-

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

The credit points are awarded after the module examination (MAP) was passed.
The credit points are awarded after all module examinations (MTP) were passed.

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** **Module Homepage** `http://sst.upb.de/teaching` **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Handouts and tutorial questions; literature references will be given in the first lecture
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The credit points are awarded after all module examinations (MTP) were passed.
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5)
12	**Module coordinator:** Prof. Dr. Erdal Kayacan
13	**Other Notes:** **Module Homepage** `http://sst.upb.de/teaching` **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Handouts and tutorial questions; literature references will be given in the first lecture

Optimization-Based Control Methods

Optimization-Based Control Methods

Module number: M.048.27031	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.27031 Optimization-Based Control Methods	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optimization-Based Control Methods:
None

4 **Contents:**

5 **Learning outcomes and competences:**

-

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5)
12	**Module coordinator:** Dr. Adrian Redder
13	**Other Notes:** **Module Homepage** `http://sst.upb.de/teaching` **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Handouts and tutorial questions; literature references will be given in the first lecture

<table>
<tr><th colspan="5">Reinforcement Learning</th></tr>
<tr><td colspan="5">Reinforcement Learning</td></tr>
<tr><td colspan="2">Module number:
M.048.92045</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
summer term</td></tr>
<tr><td colspan="2">Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.92045
Reinforcement Learning</td><td>2L
2Ex,
SS</td><td>60</td><td>120</td><td>C</td><td>30/30</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
None</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
None
<i>Prerequisites of course Reinforcement Learning:</i>
Recommended: It is recommended to have a sound basic knowledge in the field of system and control theory. Ideally, the students have knowledge in the field of un-/supervised machine learning and numerical optimization. In addition, at least some experience with Python will be advantageous for the exercise and tutorial tasks.</td></tr>
</table>

4	**Contents:** *Contents of the course Reinforcement Learning:* The course covers the basics of reinforcement learning (RL) in an engineering context. RL stands for a series of methods of machine learning in which an agent independently learns a strategy (policy) to maximize the rewards received during interaction with an (unknown) system. This can be, for example, a control loop in which an adaptive controller tries to determine an optimal control law from previous observations of the control and measurement variables, which maximizes certain benchmark criteria with regard to controller performance. Well-known fields of application include the operation of autonomous vehicles and industrial robots or the identification of optimal strategies in the context of leisure games. The course has an application-oriented focus in the engineering sciences but is also designed for students of natural sciences (e.g. computer science, mathematics). In addition to teaching the methodological fundamentals within the lecture, great importance is attached to practical implementation and programming tasks during the exercise and tutorial hours. The course will cover the following content: • Conceptual basics and historical overview • Markov decision processes • Dynamic programming • Monte Carlo learning • Temporal difference learning • Bootstrapping • Function approximation and deep learning • On- and Off-policy strategies • Policy gradient methods • Trust region methods
5	**Learning outcomes and competences:** **Domain-specific competences** After attending the course, the students are able to • differentiate, apply and analyze RL methods, • name and explain differences as well as advantages and disadvantages of RL compared to neighboring approaches (e.g. model-predictive control), • educate themselves independently in this branch of science on the basis of the methods learned for the analysis and synthesis of RL techniques. **Interdisciplinary competences** The students • can apply or transfer the acquired knowledge to interdisciplinary problems, • have gained practical experience in programming which they can use across domains and • are able to critically evaluate methods and results.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Dr Jarren Lange
13	**Other Notes:** *Remarks of course Reinforcement Learning:* **Course homepage** `https://en.ei.uni-paderborn.de/rat` https://github.com (open-source course material) **Implementation** • Slide-based lecture, which also serves as lecture notes. • Presence exercises with tutorial sheets (with many programming tasks) **Main literature** • Richard S. Sutton, Andrew G. Barto, „Reinforcement Learning“, 2. Ed., MIT Press, 2018 • David Silver, „Reinforcement Learning“ (Skriptum), University College London, 2015

Assessments (6):

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

Robotics			
Robotics			
Module number: M.048.92012	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92012 Robotics	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Robotics:
None

4 **Contents:**

Contents of the course Robotics:
Short Description
The course “Robotics” is a fundamental module in the catalog “Cognitive Systems” of the Electrical Engineering Master’s program and related degree programs. It is the first of two courses that cover the relevant concepts and techniques in the field of robot manipulators and mobile robots. This course concentrates on modeling and controlling robot arms, while its successor in the winter semester (Advanced Topics in Robotics (L.048.23020 / L.048.92006) focuses on mobile robots. The challenges for the development of autonomous intelligent systems will be analyzed and the current solutions will be presented.
Contents

- Sensors, effectors, actuators
- Homogenous coordinates, general transformations, Denavit-Hartenberg parameters
- Kinematics and dynamics of robot arms and mobile robots

After the presentation of methods in the lecture, the students will use Matlab and Octave to implement them.

5 **Learning outcomes and competences:**

Domain competence:
The students

- know how to transfer basic methods from control and system theory to robotics and
- are able to apply adequate methods to model as well as plan and control the movements of robot arms.

Key qualifications:
The students are able to identify and evaluate the function and behavior of robots and their integration into the social and economic environment while also considering ethical aspects.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Bärbel Mertsching

13	**Other Notes:** *Remarks of course Robotics:* **Course Homepage** [http://getwww.uni-paderborn.de/teaching/robotik] **Course Documents** see PANDA ([https://panda.uni-paderborn.de]) **References (excerpt)** • Mertsching, Bärbel: Robotics (lecture notes) • McKerrow, Phillip J.: Introduction to Robotics. Addison-Wesley, 1991 • Lynch, Kevin M. and Park, Frank C.: Modern Robotics: Mechanics, Planning, and Control. Cambridge University Press, 2017. ISBN-13 : 978-1107156302

Ultraschallmesstechnik			
Ultrasonic measurement technology			
Module number: M.048.27015	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.27015 Ultrasonic Measurement Technology	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Ultraschallmesstechnik:
None

4 **Contents:**

Contents of the course Ultraschallmesstechnik:
Short description
The course Ultrasonic Measurement Technology deals with the phenomena of propagation of mechanical waves in solids, liquids and gases. Based on this the most important acoustic measurement principles for the determination of acoustic material parameters, geometric and technical process parameters as well as their application in process and production engineering are described. The application of sound and ultrasound for non-destructive material diagnostics as well as for ultrasonic tomography are covered in detail.
Contents
The Ultrasonic Metrology lecture covers the following topics:

- Acoustic and sound field characteristics.
- Fundamentals of wave propagation
- Ultrasonic sensor design (experimental realization)
- Methods for measurement and visualization of ultrasonic fields (needle and membrane hydrophone, schlieren measuring station, laser vibrometry. . .)
- Metrological methods for acoustic material data determination (sound velocity, sound characteristic impedance. . .)
- Application of ultrasound for non-destructive testing (NDT) and acoustic emission analysis
- Application of ultrasound and in process measurement technology (distance, flow, level. . .)

5	**Learning outcomes and competences:** **Specialized competence:** After attending the course, students will be able to, • use ultrasound to determine acoustic and non-acoustic quantities. **Cross-disciplinary competencies:** The students • are able to apply the knowledge and skills across disciplines and to complex problems, • are able to develop targeted solutions on the basis of systematic problem analysis, • are able to familiarize themselves with tangential fields of work due to the method-oriented knowledge transfer.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Bernd Henning

Assessments (6):

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

13	**Other Notes:** *Remarks of course Ultraschallmesstechnik:* **Course Homepage** `http://emt.upb.de` **Methodical implementation** • Lectures with slide presentation of extensive correlations • Practical work in groups using measurement techniques in the laboratory **Learning materials, references** • Provision of a script; references to textbooks from the textbook collection will be announced.

Umweltmesstechnik

Environmental monitoring and measuring technologies

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.22010	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.22010 Environmental Monitoring and Measuring Technologies	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Umweltmesstechnik:
None

4 **Contents:**

Contents of the course Umweltmesstechnik:
Short Description:
The ever more intensive use of natural resources is leading to increasing environmental pollution. This course deals with the problems of certain selected impact mechanisms in relation to the impact sites or habitats. The relevant quantities will be characterised and the measurement principles and methods suitable for determining them will be described. In particular, the explanations concentrate on the metrological determination of contamination and monitoring of air, water and soil.
Contents:
The lecture Environmental Monitoring and Measuring Technologies is structured as follows

- Legal framework of environmental protection
- Significance and tasks of environmental monitoring and measuring technology
- Explanation of the mechanisms of action in the increasingly intensive use of natural resources as well as the increasing hazard potential through the use of technologies
- Chemosensor technology and sample preparation
- Measurement principles and methods of environmental measurement technology
- Optodes and optical measurement and analysis technology
- Sensors for liquid analysis
- Sensors for gas analysis

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, students are able to

- analyse and understand the mechanisms of action in increasing environmental problems,
- to select suitable measurement principles or measurement techniques for selected measurement tasks, considering the concrete measurement conditions,
- characterise and interpret measurement results.

Key qualifications:
The Students

- can apply the acquired knowledge and skills in an interdisciplinary manner and with complex issues,
- are able to develop targeted solutions based on systematic problem analysis,
- are capable of familiarising themselves with relevant fields of work due to the method-oriented knowledge transfer.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination	120-180 min or 30-45 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5

12 **Module coordinator:**

Prof. Dr. Bernd Henning

13	**Other Notes:** *Remarks of course Umweltmesstechnik:* **Module Homepage** `http://emt.upb.de` **Methodical implementation** • Lectures with slide presentation of extensive correlations • Practical work in groups with measurement technology in the laboratory **Learning materials, references** Provision of a script; references to textbooks from the textbook collection will be announced.

3.4 Specialisation Area “Embedded Systems”

Specialisation Area	Embedded Systems
Modules	* Advanced VLSI Design * Algorithms and Tools for Test and Diagnosis of Systems on a Chip * Integrated Circuits for Wireless Communications * Model-Based Systems Engineering * Reconfigurable Computing * Fast Integrated Circuits for Wireline Communications * Software Quality Assurance * VLSI Testing
Catalogue advisor	Hellebrand, Sybille, Prof. Dr.
Credits ECTS	6
Learning objectives	

The modules from this specialisation area enable specialisation in the field of embedded systems.

Advanced VLSI Design

Advanced VLSI Design

Module number: M.048.92043	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92043 Advanced VLSI Design	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced VLSI Design:
Recommended: Fundamentals of Digital Circuits / Fundamentals of VLSI Design
Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

Contents of the course Advanced VLSI Design:
Short Description
The course provides basic knowledge about the modern application-oriented modeling, simulation, analysis, and synthesis of digital systems at different abstraction levels to chip layout.
Contents
In today's practice, chip design consists of the combined application of various languages, methods, and tools for the modeling, simulation, and synthesis of electronic circuits. Along the modern abstraction-based design flow of digital systems (electronic system level to chip layout), the course provides basic knowledge of the main description languages and their application in modeling, simulation, analysis and synthesis. This includes basic principles and application of the IEEE standard system/hardware description languages SystemVerilog, SystemC, Verilog, and VHDL, in conjunction with additional formats, e.g., SDF and UPF for time and power annotation. For their application, the fundamental principles of test environments for simulation, timing and power analysis, logic synthesis and physical design of digital circuits. Exercises will provide hands-on labs based on commercial tools from Mentor Graphics, Synopsys and, Cadence Design Systems.

5 **Learning outcomes and competences:**

Domain competence:
After the course students are able

- to model, simulate, analyze and synthesize simple digital circuits at different abstraction levels and
- to apply the most important commercial tools for simulation, analysis and synthesis of digital circuits.

Key qualifications:
After the course students are able

- to assess, select and apply modern digital circuit description languages for their different applications,
- apply the different methods and tools in the modern VLSI design.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** apl. Prof. Dr. Wolfgang Müller
13	**Other Notes:** *Remarks of course Advanced VLSI Design:* **Course Homepage** `www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/advanced-vlsi-design` **Implementation** * Vorlesung mit Beamer und White-Board * Übungen mit Übungsblättern am Computer * Lecture with LCD projector and white board * Exercises with assignments and hands-on labs **Teaching Material, Literature** • Lecture notes and exercise sheets will be provided via PAUL • IEEE standard reference manuals: IEEE Std 1800/1685/1666/1364/1076/1801/1497 • Specific references for individual teaching units

Algorithms and Tools for Test and Diagnosis of Systems on a Chip

Algorithms and Tools for Test and Diagnosis of Systems on a Chip

Module number: M.048.92007	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer- / winter term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92007 Algorithms and Tools for Test and Diagnosis of Systems on a Chip	2L 2Ex, WS+SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Recommended: VLSI Testing, (Introduction to Algorithms)

4 **Contents:**

Contents of the course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Short Description
The course “Algorithms and Tools for Test and Diagnosis of Systems on Chip” deals with advanced topics in test and diagnosis of integrated systems. The focus is on algorithms and tools for computer-aided preparation and application of test and diagnosis procedures.
** Contents**
Topics include but are not restricted to:

- Advanced techniques for built-in self-test and embedded test
- Built-in diagnosis
- Test of robust and self-adaptive systems
- Adaptive Testing

<table>
<tr><td>5</td><td>

Learning outcomes and competences:

Domain competence:
After attending the course, the students will be able

- to describe recent approaches in test and diagnosis,
- to explain and apply the underlying models and algorithms,
- to explain the specific challenges of nanoscale integration and evaluate test strategies accordingly.

Key qualifications:
The students are able

- to apply their basic knowledge for studying and understanding new approaches from the state of the art literature,
- to present the new contents in a conference style presentation, and
- to describe the new contents in a scientific manuscript.

</td></tr>
<tr><td>6</td><td>

Assessments:

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table>

</td></tr>
<tr><td>7</td><td>

Study Achievement:

none

</td></tr>
<tr><td>8</td><td>

Prerequisites for participation in examinations:

None

</td></tr>
<tr><td>9</td><td>

Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.

</td></tr>
<tr><td>10</td><td>

Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).

</td></tr>
<tr><td>11</td><td>

Reuse in degree courses or degree course versions :

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

</td></tr>
<tr><td>12</td><td>

Module coordinator:

Prof. Dr. Sybille Hellebrand

</td></tr>
</table>

13 **Other Notes:**

Remarks of course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Module Homepage
`http://ei.uni-paderborn.de/en/electrical-engineering/date/teaching/electrical-engineering/overview`
Implementation

- Lecture based on slide presentation, extensions on blackboard
- Self-study on recent approaches based on recent conference and journal publications
- Oral presentation
- Manuscript

Teaching Material, Literature

- Lecture slides
- Additional material can be found in panda
- Michael L. Bushnell, Vishwani D. Agrawal, „Essentials of Electronic Testing for Digital, Memory, and Mixed-Signal VLSI Circuits,“ Kluwer Academic Publishers,2000
- Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, „VLSI Test Principles and Architectures: Design for Testability,“ Morgan Kaufmann Series in Systems on Silicon, ISBN: 0123705975
- Artikel aus Fachzeitschriften und Konferenzbänden / Articles from Journals and Conference Proceedings (e.g. IEEE Transactions on Computers, IEEE Transactions on CAD of Integrated Circuits and Systems, IEEE International Test Conference, etc.)

Integrierte Schaltungen für die drahtlose Kommunikation			
Integrated Circuits for Wireless Communications			
Module number: M.048.25017	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.25017 Integrated Circuits for Wireless Communications	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Integrierte Schaltungen für die drahtlose Kommunikation:
Recommended: Lecture Schaltungstechnik rsp. Circuit and System Design. Helpful supplement: Lecture “Wireless Communications” of Prof. Hab-Umbach.

4 **Contents:**

Contents of the course Integrierte Schaltungen für die drahtlose Kommunikation:
Short Description
Mobile communications, wireless networks, and RFID technology are application examples of wireless communications. Wireless communications has found widespread use in everyday life and will become even more important in the future. The design of electronic circuits for radio frequencies requires a good system knowledge with respect to typical transmitter and receiver architectures in wireless communications, components, and radio signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required. Goal of the lecture is to convey a methodical approach to the design of integrated circuits for wireless communications. A part of the exercises will pertain to calculation of circuit design problems another will be performed in small teams as a hands-on exercise using modern IC design software.
Contents
The lecture deals with analysis and design of radio frequency integrated circuits for wireless communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures “Schaltungstechnik” rsp. “Circuit and System Design”. The following topics will be addressed:

- Transmitter and receiver architectures for wireless communications
- System Theory Basics
    - Signals and noise
    - Modulation and demodulation
    - Transmission properties of wireless communcations systems
- Semiconductor technologies and integrated high-frequency devices
- Amplifiers (low-noise and variable-gain amplifiers)
- Mixers
- Oscillators
- Frequency synthesizer PLLs

5 **Learning outcomes and competences:**

The students will be able

- to describe architectures and circuits of wireless communication systems
- to describe and calculate fundamental signal transmission properties of wireless systems
- to apply design methods to design components of radio frequency ICs

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Oral Examination	30-45 min	100%

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr.-Ing. J. Christoph Scheytt
13	**Other Notes:** *Remarks of course Integrierte Schaltungen für die drahtlose Kommunikation:* **Course Homepage** `https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/integrierte-schaltungen-fuer-die-drahtlose-kommunikation/` **Implementation** • Lecture with Powerpoint presentation and handwritten mathematical derivations using tablet and beamer • Exercises partly as handwritten calculation exercises using tablet and beamer and partly as practical IC design exercises using IC design software **Teaching Material, Literature** Lecture slides and videos as well as exercise slides will be made available. • Behzad Razavi “RF Microelectronics”, Prentice Hall, 2011 • Thomas Lee “The Design of CMOS Radio-Frequency Integrated Circuits”, Cambridge University Press 2003

Model-Based Systems Engineering			
Model-Based Systems Engineering			
Module number: M.079.4062	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7058 Model-Based Systems Engineering	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Model-Based Systems Engineering:
Recommended Proficiencies
Basics of Systems Engineerings

4 **Contents:**

Contents of the course Model-Based Systems Engineering:
Due to the technical change from mechatronic to intelligent technical systems (ITS), companies and development teams are facing many challenges. A key factor is the increase in complexity and networking of systems (products). Existing approaches in product development cannot cover this efficiently and effectively. Model-based Systems Engineering (MBSE) presents itself as a promising approach to solve these challenges. MBSE sees itself as a further development of systems engineering and builds on its foundations. Systems engineering, which is primarily based on documents, is extended by the introduction of models.
The course includes the following content:

- Intelligent Engineering Systems
- Model-based Systems Engineering 101
- Systems Modeling Fundamentals
- Languages and Methods - CONSENS, SysML
- Systems Architecting
- IT Tools for MBSE

<table>
<tr><td>5</td><td>Learning outcomes and competences:
The students
acquire a solid understanding of Model-Based System Engineering
know different methods, languages, and tools
are able to apply the knowledge they have gained
are able to work out solutions independently and communicate them to the lecturers.</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or oral examination or report</td><td>90-120 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
none</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4, Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr.-Ing. Roman Dumitrescu</td></tr>
</table>

13 **Other Notes:**

Remarks of course Model-Based Systems Engineering:
Implementation Method
The module consists of two parts

1. lecture with slides: basics and concepts are explained in the lecture and illustrated with examples.
2. exercises (tutorial): In the exercises, knowledge is transferred and the concepts are applied. The exercises have to be prepared by the students themselves.

Learning Material, Literature

- Gausemeier, J.; Dumitrescu, R.; Steffen, D.; Czaja, A.; Wiederkehr, O.; Tschirner, C.: Systems Engineering in industrial practice. Heinz Nixdorf Institute, University Paderborn, 2013, Under: https://www.hni.uni-paderborn.de/en/spe/systemsengineering/
- Dumitrescu, R.; Albers, A.; Riedel, O.; Stark, R.;Gausemeier, J. (Eds): Engineering in Germany – Status quo in Business and Science. Federal Ministry of Education and Research, 2021 Under: https://www.advanced-systems-engineering.de/#studie
- Additional literature will be announced in the course.

Reconfigurable Computing			
Reconfigurable Computing			
Module number: M.079.4043	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7034 Reconfigurable Computing	L2 Ex3	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Reconfigurable Computing:
Recommended Proficiencies
Knowledge of the Bachelor-level courses Digital Design, Programming, and Data Structures and Algorithms are beneficial.

4 **Contents:**

Contents of the course Reconfigurable Computing:
The course Reconfigurable Computing introduces into the field of computing with reprogrammable hardware structures. Computing systems built from reprogrammable hardware structures do not rely on a fixed hardware, but adapt their hardware architecture to the application under execution. The field was formed in the early 1990s when Field-programmable Gate Arrays (FPGAs) became commercially available that were powerful enough to be used for computing. Today, FPGA-based high-performance systems have outperformed state-of-the-art computers for many problems including database search, genomic sequence scanning, and cryptography. In embedded systems, FPGAs accelerate system functions, reduce system cost and energy consumption, and enable hardware-on-demand functionality. The course covers the following topics:

- Introduction to reconfigurable computing
- Evolution of programmable hardware devices
- FPGA architectures
- Computer-aided design for FPGAs
- High-level languages for programming FPGAs
- Application domains for FPGAs
- Comparison of devices, technologies, and reconfigurable systems

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Students will be able to
compare different reprogrammable hardware devices and describe their historical development,
name the design steps and problems when designing with FPGAs,
analyse algorithms for the design steps and apply them to examples,
compare and evaluate current approaches to programming FPGAs,
justify the suitability of different reprogrammable hardware components for different areas of application, and
implement functions of medium complexity with modern FPGA design tools.</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or oral examination or report</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
<table>
<tr><th>zu</th><th>Type of achievement</th><th>Duration or Scope</th><th>SL / QT</th></tr>
<tr><td>a)</td><td>Assignments, course paper or progress reports</td><td></td><td>CA</td></tr>
</table></td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
Passing of course achievement</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Marco Platzner</td></tr>
</table>

13	**Other Notes:** *Remarks of course Reconfigurable Computing:* **Implementation Method** The course consists of a lecture, and pencil&paper as well as practical exercises. The lecture is held with a beamer and blackboard. In the pencil&paper exercises, problems are handed out and their solutions are presented and discussed in a practice session. In addition, quizzes are offered for self-assessments. In the practical exercises, a tutorial on the design with FPGAs is carried out and then tasks are handed out, which are implemented as design or programming examples in groups of one to three participants. **Learning Material, Literature** • Lecture slides, assignment sheets for paper&pencil exercises, quizzes • Tutorial, assignment sheets for design and programming examples, technical documentation • Selected scientific articles • Additional literature will be announced in the course.

Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation

Fast Integrated Circuits for Wireline Communications

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.25019	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de / en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.25019 Fast Integrated Circuits for Wireline Communications	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:
Recommended: Module “Schaltungstechnik” of the Bachelor Electrical Engineering or module “Circuit and System Design” of the Master “Electrical Systems Engineering” or comparable modules / lectures

4 **Contents:**

Contents of the course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:
Short Description
Nowadays commercial fiber-optic communication systems reach very high data rates of 100 Gb/s per optical channel and several Tb/s in a single fiber. In a similar way very high data rates of more than 10 Gb/s occur at a single package pin of electronic chips. These signals are to be transmitted over printed circuit boards and inexpensive serial cables. In the future the progress of CMOS technology and communication technology will push speed of fiber-optic and wire-line communication continuously to ever higher data rates. The design of electronic circuits for high bandwidth rsp. data rates requires a good system knowledge with respect to typical transmitter and receiver architectures, components, and signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required. Goal of the lecture is to enable the student to utilize a methodological approach for the design of fast integrated electronic circuits for digital wired communications. A part of the exercises will be carried out using modern industry-standard IC design software.
Contents
The lecture deals with analysis and design of fast integrated electronic circuits for digital broadband communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures “Schaltungstechnik” rsp. “Circuit and System Design”. The lecture deals with:

- Transmitter and receiver architectures for fiber-optic communications
- Transmitter and receiver architectrues for chip-to-chip communications
- System design
- Semiconductor technology and integrated high-frequency devices
- Broadband amplifiers
- Current-mode logic
- Transmitter and receiver circuits
- PLLs for frequency synthesis and clock recovery
- Measurement methods

5 **Learning outcomes and competences:**

Domain competence:
The student will be able to:

- describe and analyze transmitter and receiver architectures for broadband communication links
- understand and describe semiconductor technologies and integrated high-frequency devices for broadband circuits
- to analyze circuit design techniques for transmitter and receiver circuits and describe ways to optimize them
- to describe circuits in PLL technique for frequency synthesis and clock recovery
- to describe measurement methods

Key qualifications:
The students will learn how different interdisciplinary scientific domains and their methods - like mathematical signal and system analysis, non-linear and linear circuit analysis, semiconductor physics, semiconductor devices and high-frequency engineering - are applied together for the development of communications application.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Oral Examination	30-45 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12 **Module coordinator:**

Prof. Dr.-Ing. J. Christoph Scheytt

13 **Other Notes:**

Remarks of course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:
Course Homepage
`https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/fast-integrated-circuits-for-wireline-communications/`
Implementation
Lecture with Exercises (including computer-aided design using electronic design software)
Teaching Material, Literature
Handouts and literature references will be given in the lecture.

- E. Säckinger, “Broadband Circuits for Optical Fiber Communication”, Wiley, 2005
- B. Razavi, “Design of Integrated Circuits for Optical Communications”, McGraw-Hill, 2003

Comments
As part of the lecture a 2-day excursion to IHP Leibnizinstitute for High-Performance Microelectronics in Frankfurt (Oder) is offered which includes the visit of a modern chip fabrication facility (participation in the excursion is voluntary).

<table>
<tr><td colspan="4">VLSI-Testing</td></tr>
<tr><td colspan="4">VLSI-Testing</td></tr>
<tr><td>Module number:
M.048.92027</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
winter term</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
P</td></tr>
</table>

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92027 VLSI Testing	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course VLSI Testing:
Recommended: Digital Design

4 **Contents:**

Contents of the course VLSI Testing:
Short Description
The course “VLSI Testing” focuses on techniques for detecting hardware defects in microelectronic circuits. Algorithms for test data generation and test response evaluation as well as hardware structures for design for test (DFT) and on-chip test implementation (BIST) are presented.
Contents
In detail the following topics are covered:

- Fault models
- Testability measures and design for test (DFT)
- Logic and fault simulation
- Automatic test pattern generation (ATPG)
- Built-in self-test (BIST), in particular test data compression and test response compaction
- Memory test

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Domain competence:
After attending the course, the students will be able
• to describe fault models, DFT techniques, and test tools,
• to explain and apply the underlying models and algorithms for fault simulation and test generation,
• to analyze systems with respect to their testability and to derive appropriate test strategies.
Key qualifications:
The students
• are able to apply the practiced strategies for problem solving across varying disciplines,
• have experience in presenting their solutions to their fellow students, and
• know how to improve their competences by private study.</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
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</table>
</td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4, Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Sybille Hellebrand</td></tr>
</table>

13 **Other Notes:**

Remarks of course VLSI Testing:
Course Homepage
`https://ei.uni-paderborn.de/en/electrical-engineering/date/teaching/electrical-engineering/overview`
Implementation

- Lecture based on slide presentation, extensions on blackboard
- Exercises in small groups based on exercise sheets with students presenting their own solutions
- Hands-on exercises using various software tools

Teaching Material, Literature
Additional material can be found in panda

- Michael L. Bushnell, Vishwani D. Agrawal, „Essentials of Electronic Testing for Digital, Memory, and Mixed-Signal VLSI Circuits,“Boston, Dordrecht, London: Kluwer Academic Publishers, 2000
- Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, „VLSI Test Principles and Architectures: Design for Testability,“ Morgan Kaufmann Series in Systems on Silicon, ISBN: 0123705975

3.5 Specialisation Area “Nano/Microelectronics”

Specialisation Area	Nano/Microelectronics
Modules	* Advanced VLSI Design * Algorithms and Tools for Test and Diagnosis of Systems on a Chip * Introduction to High-Frequency Engineering * High Frequency Engineering * Integrated Circuits for Wireless Communications * Optoelectronics * Fast Integrated Circuits for Wireline Communications * VLSI Testing
Catalogue advisor	Hellebrand, Sybille, Prof. Dr.
Credits ECTS	6
Learning objectives	

The modules from this specialisation area enable specialisation in the field of nano- and microelectronics.

Advanced VLSI Design			
Advanced VLSI Design			
Module number: M.048.92043	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92043 Advanced VLSI Design	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced VLSI Design:
Recommended: Fundamentals of Digital Circuits / Fundamentals of VLSI Design
Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

Contents of the course Advanced VLSI Design:
Short Description
The course provides basic knowledge about the modern application-oriented modeling, simulation, analysis, and synthesis of digital systems at different abstraction levels to chip layout.
Contents
In today's practice, chip design consists of the combined application of various languages, methods, and tools for the modeling, simulation, and synthesis of electronic circuits. Along the modern abstraction-based design flow of digital systems (electronic system level to chip layout), the course provides basic knowledge of the main description languages and their application in modeling, simulation, analysis and synthesis. This includes basic principles and application of the IEEE standard system/hardware description languages SystemVerilog, SystemC, Verilog, and VHDL, in conjunction with additional formats, e.g., SDF and UPF for time and power annotation. For their application, the fundamental principles of test environments for simulation, timing and power analysis, logic synthesis and physical design of digital circuits. Exercises will provide hands-on labs based on commercial tools from Mentor Graphics, Synopsys and, Cadence Design Systems.

5 **Learning outcomes and competences:**

Domain competence:
After the course students are able

- to model, simulate, analyze and synthesize simple digital circuits at different abstraction levels and
- to apply the most important commercial tools for simulation, analysis and synthesis of digital circuits.

Key qualifications:
After the course students are able

- to assess, select and apply modern digital circuit description languages for their different applications,
- apply the different methods and tools in the modern VLSI design.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** apl. Prof. Dr. Wolfgang Müller
13	**Other Notes:** *Remarks of course Advanced VLSI Design:* **Course Homepage** `www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/advanced-vlsi-design` **Implementation** * Vorlesung mit Beamer und White-Board * Übungen mit Übungsblättern am Computer * Lecture with LCD projector and white board * Exercises with assignments and hands-on labs **Teaching Material, Literature** • Lecture notes and exercise sheets will be provided via PAUL • IEEE standard reference manuals: IEEE Std 1800/1685/1666/1364/1076/1801/1497 • Specific references for individual teaching units

Algorithms and Tools for Test and Diagnosis of Systems on a Chip

Algorithms and Tools for Test and Diagnosis of Systems on a Chip

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92007	180	6	summer- / winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92007 Algorithms and Tools for Test and Diagnosis of Systems on a Chip	2L 2Ex, WS+SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Recommended: VLSI Testing, (Introduction to Algorithms)

4 **Contents:**

Contents of the course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Short Description
The course “Algorithms and Tools for Test and Diagnosis of Systems on Chip” deals with advanced topics in test and diagnosis of integrated systems. The focus is on algorithms and tools for computer-aided preparation and application of test and diagnosis procedures.
** Contents**
Topics include but are not restricted to:

- Advanced techniques for built-in self-test and embedded test
- Built-in diagnosis
- Test of robust and self-adaptive systems
- Adaptive Testing

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the students will be able

- to describe recent approaches in test and diagnosis,
- to explain and apply the underlying models and algorithms,
- to explain the specific challenges of nanoscale integration and evaluate test strategies accordingly.

Key qualifications:
The students are able

- to apply their basic knowledge for studying and understanding new approaches from the state of the art literature,
- to present the new contents in a conference style presentation, and
- to describe the new contents in a scientific manuscript.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Sybille Hellebrand

13 **Other Notes:**

Remarks of course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Module Homepage
`http://ei.uni-paderborn.de/en/electrical-engineering/date/teaching/electrical-engineering/overview`
Implementation

- Lecture based on slide presentation, extensions on blackboard
- Self-study on recent approaches based on recent conference and journal publications
- Oral presentation
- Manuscript

Teaching Material, Literature

- Lecture slides
- Additional material can be found in panda
- Michael L. Bushnell, Vishwani D. Agrawal, „Essentials of Electronic Testing for Digital, Memory, and Mixed-Signal VLSI Circuits,“ Kluwer Academic Publishers,2000
- Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, „VLSI Test Principles and Architectures: Design for Testability,“ Morgan Kaufmann Series in Systems on Silicon, ISBN: 0123705975
- Artikel aus Fachzeitschriften und Konferenzbänden / Articles from Journals and Conference Proceedings (e.g. IEEE Transactions on Computers, IEEE Transactions on CAD of Integrated Circuits and Systems, IEEE International Test Conference, etc.)

Einführung in die Hochfrequenztechnik			
Introduction to High-Frequency Engineering			
Module number: M.048.40003	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language:	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.11004 Introduction to High-Frequency Engineering	2L 2Ex, WS	60	120	CE	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Einführung in die Hochfrequenztechnik:
Recommended: Prior knowledge from the modules Higher Mathematics and Foundations of Electrical Engineering.

4 **Contents:**

Contents of the course Einführung in die Hochfrequenztechnik:
Short Description
The course Introduction to High-Frequency Engineering provides basic knowledge of high-frequency engineering in particular with respect to signal propagation along transmission lines on circuit boards and integrated circuits. This knowledge is prerequisite for the continuative courses High-Frequency Engineering, Optical Communication, and High-Frequency Electronics.
Contents
In the first part of the course Introduction to High-Frequency Engineering, an equivalent circuit togehther with primary transmission line parameter is introduced. The resulting telegraph equation is solved for various boundary conditions. In particular, stationary processes and lossless transmission lines are considered and the Smith diagram is introduced. The gained knowledge is used to dimension circuits comprising distributed and lumped components, in particular matching networks. In the second part, high-frequency aspects of circuit theory are covered. In particular, circuits comprising distributed and lumped elements are consistently described and classified by scattering parameters, and gain definitions are derived.

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the students will be able to

- describe circuits comprising distributed and lumped components,
- to analyze,
- and to design the latter.

Key qualifications:
The students

- can use of methodic knowledge for systematic problem analysis,
- get familiar with the CAD system ADS, which is commonly used in industry
- and gain foreign language competences related to the field.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4)

12 **Module coordinator:**

Prof. Dr. Andreas Thiede

13	**Other Notes:** *Remarks of course Einführung in die Hochfrequenztechnik:* **Course Homepage** `http://groups.uni-paderborn.de/hfe/teaching/hft.html` **Implementation** • Lectures with black board presentation, supported by animated graphics and transparencies, • Presence exercises with task sheets to be solved by the students together, supported by the teacher, and partially using CAD software. **Teaching Material, Literature** A. Thiede, Einführung in die Hochfrequenztechnik, Vorlesungsskript Universität Paderborn continuative and deepening literature A. Thiede, Integrierte Hochfrequenzschaltkreise, Springer Vieweg Verlag (YDA2058) P. Vielhauer, Lineare Netzwerke, Verlag Technik und Hüthig (65 YCF 1469) M. Hoffmann, Hochfrequenztechnik, Springer Verlag (51 YDA 1913) O. Zinke, H. Brunswig, Hochfrequenztechnik, Bd.1+2, Springer Verlag (51 YDA 1086) G. Gonzalez, Microwave Transistor Amplifiers, Prentice Hall (51 YEP 3142) P.C.L. Yip, High-Frequency Circuit Design and Measurements, Chapman&Hall (51 YDA 1751) R.E. Collin, Foundations for Microwave Engineering, Mc Graw-Hill (51 YGA 1240)

<table>
<tr><th colspan="4">High Frequency Engineering</th></tr>
<tr><td colspan="4">High Frequency Engineering</td></tr>
<tr><td>Module number:
M.048.92002</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
winter term</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
</table>

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92002 High Frequency Engineering	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course High Frequency Engineering:
None

4 **Contents:**

Contents of the course High Frequency Engineering:
Short Description
This lecture gives application-oriented knowledge in high frequency engineering. Furthermore, it gives knowledge in active and passive high-frequency circuits.
Contents
The lecture High-Frequency Engineering extends the content of the lecture Theoretische Elektrotechnik by further application-relevant knowledge. The aim is to qualify the students for development tasks for example in the radio frequency part of a mobile telephone. But considerations of high-frequency engineering are also needed in prevalent digital circuits. The emphases of the lecture are passive devices, high-frequency properties of fundamental transistor circuits, linear and nonlinear amplifiers, noisy multiports, mixers, oscillators, injection-locking and phase-locked loop.

5 **Learning outcomes and competences:**

Professional Competence
After attending the course, the students will be able, in the taught extent, to understand the function of components, circuits and systems of high-frequency engineering, to model and to apply them.
(Soft) Skills
The students

- are able to apply the knowledge and skills to a wide range of disciplines,
- are able to make use of a methodical procedure when undertaking systematic analysis and
- are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Reinhold Noé

13	**Other Notes:** *Remarks of course High Frequency Engineering:* **Course Homepage** `http://ont.upb.de` **Implementation** Lecture and exercise **Teaching Material, Literature** Scripts, exercise sheets and advanced literature (excerpt): • Thiede, A.: Skriptum Hochfrequenzelektronik/High-Frequency Electronics, Universität Paderborn • Sze, S. M.: High Speed Semiconductor Devices, John Wiley & Sons, 1990 • Herbst, L. J.: Integrated Circuit Engineering, Oxford University Press, 1996 • Yip, P. C. L.: High-Frequency Circuit Design and Measurement, Chapman & Hall, 1996 • Gonzalez, G.: Microwave Transistor Amplifiers, Prentice Hall, 1997 • Hoffmann, M.: Hochfrequenztechnik, Springer, 1997

Integrierte Schaltungen für die drahtlose Kommunikation			
Integrated Circuits for Wireless Communications			
Module number: M.048.25017	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.25017 Integrated Circuits for Wireless Communications	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Integrierte Schaltungen für die drahtlose Kommunikation:
Recommended: Lecture Schaltungstechnik rsp. Circuit and System Design. Helpful supplement: Lecture “Wireless Communications” of Prof. Hab-Umbach.

4 **Contents:**

Contents of the course Integrierte Schaltungen für die drahtlose Kommunikation:

Short Description

Mobile communications, wireless networks, and RFID technology are application examples of wireless communications. Wireless communications has found widespread use in everyday life and will become even more important in the future. The design of electronic circuits for radio frequencies requires a good system knowledge with respect to typical transmitter and receiver architectures in wireless communications, components, and radio signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required. Goal of the lecture is to convey a methodical approach to the design of integrated circuits for wireless communications. A part of the exercises will pertain to calculation of circuit design problems another will be performed in small teams as a hands-on exercise using modern IC design software.

Contents

The lecture deals with analysis and design of radio frequency integrated circuits for wireless communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures “Schaltungstechnik” rsp. “Circuit and System Design”. The following topics will be addressed:

- Transmitter and receiver architectures for wireless communications
- System Theory Basics
    - Signals and noise
    - Modulation and demodulation
    - Transmission properties of wireless communcations systems
- Semiconductor technologies and integrated high-frequency devices
- Amplifiers (low-noise and variable-gain amplifiers)
- Mixers
- Oscillators
- Frequency synthesizer PLLs

5 **Learning outcomes and competences:**

The students will be able

- to describe architectures and circuits of wireless communication systems
- to describe and calculate fundamental signal transmission properties of wireless systems
- to apply design methods to design components of radio frequency ICs

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Oral Examination	30-45 min	100%

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr.-Ing. J. Christoph Scheytt
13	**Other Notes:** *Remarks of course Integrierte Schaltungen für die drahtlose Kommunikation:* **Course Homepage** `https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/integrierte-schaltungen-fuer-die-drahtlose-kommunikation/` **Implementation** • Lecture with Powerpoint presentation and handwritten mathematical derivations using tablet and beamer • Exercises partly as handwritten calculation exercises using tablet and beamer and partly as practical IC design exercises using IC design software **Teaching Material, Literature** Lecture slides and videos as well as exercise slides will be made available. • Behzad Razavi “RF Microelectronics”, Prentice Hall, 2011 • Thomas Lee “The Design of CMOS Radio-Frequency Integrated Circuits”, Cambridge University Press 2003

Optoelectronics			
Optoelectronics			
Module number: M.048.26011	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.26011 Optoelectronics	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optoelectronics:
None

4 **Contents:**

Contents of the course Optoelectronics:
Short description
The lecture Optoelectronics covers the fundamental aspects of optoelectronic devices, starting with semiconductor materials and their interaction with light and photons, to the electronic aspects of the components, and finally to the use of quantum mechanical effects to optimise modern components for their respective areas of application, such as in lighting systems, renewable energy, broadband optical communication systems or in medical technology.
Contents
In the first part of the lecture, the basics of semiconductors (lattice structure, band structure, direct-indirect semiconductors, doping, degenerate and non-degenerate semiconductors, heterostructures, quantum effects in low-dimensional semiconductors) are recapitulated. The elementary interactions between light and semiconductors (absorption, stimulated emission, spontaneous emission) and the electronic aspects of the components (p-n junction, heterojunctions) are then covered. Finally, the most important devices such as solar cells, photodiodes, light-emitting diodes and semiconductor lasers are discussed in detail and their most important parameters and optimisation strategies are explained.

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the students will be able to

- explain the basic physical properties of optoelectronic semiconductor devices based on classical and fundamental quantum mechanical descriptions,
- to describe the main concepts of optoelectronic semiconductor devices (photodiodes, solar cells, light emitting diodes, semiconductor lasers),
- categorize different device designs according to their application requirements.

Key qualifications:
The students

- can use of methodic knowledge for systematic problem analysis for a wide range of disciplines,
- will be in position to familiarise themselves independently with new generations of semiconductor devices, thanks to the comprehensive fundamental training received,
- get familiar to rate-equation models to simulate steady-state and dynamic characteristics in coupled systems,
- and gain foreign language competences related to the field.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12	**Module coordinator:** Prof. Dr.-Ing. Nils Christopher Gerhardt
13	**Other Notes:** **Module Homepage** to be announced at the start of the lecture **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Lecture notes and handouts for the tutorial; literature references will be given in the first lecture

Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation

Fast Integrated Circuits for Wireline Communications

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.25019	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de / en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.25019 Fast Integrated Circuits for Wireline Communications	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:
Recommended: Module “Schaltungstechnik” of the Bachelor Electrical Engineering or module “Circuit and System Design” of the Master “Electrical Systems Engineering” or comparable modules / lectures

4	**Contents:** *Contents of the course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:* **Short Description** Nowadays commercial fiber-optic communication systems reach very high data rates of 100 Gb/s per optical channel and several Tb/s in a single fiber. In a similar way very high data rates of more than 10 Gb/s occur at a single package pin of electronic chips. These signals are to be transmitted over printed circuit boards and inexpensive serial cables. In the future the progress of CMOS technology and communication technology will push speed of fiber-optic and wire-line communication continuously to ever higher data rates. The design of electronic circuits for high bandwidth rsp. data rates requires a good system knowledge with respect to typical transmitter and receiver architectures, components, and signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required. Goal of the lecture is to enable the student to utilize a methodological approach for the design of fast integrated electronic circuits for digital wired communications. A part of the exercises will be carried out using modern industry-standard IC design software. **Contents** The lecture deals with analysis and design of fast integrated electronic circuits for digital broadband communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures “Schaltungstechnik” rsp. “Circuit and System Design”. The lecture deals with: • Transmitter and receiver architectures for fiber-optic communications • Transmitter and receiver architectrues for chip-to-chip communications • System design • Semiconductor technology and integrated high-frequency devices • Broadband amplifiers • Current-mode logic • Transmitter and receiver circuits • PLLs for frequency synthesis and clock recovery • Measurement methods
5	**Learning outcomes and competences:** **Domain competence:** The student will be able to: • describe and analyze transmitter and receiver architectures for broadband communication links • understand and describe semiconductor technologies and integrated high-frequency devices for broadband circuits • to analyze circuit design techniques for transmitter and receiver circuits and describe ways to optimize them • to describe circuits in PLL technique for frequency synthesis and clock recovery • to describe measurement methods **Key qualifications:** The students will learn how different interdisciplinary scientific domains and their methods - like mathematical signal and system analysis, non-linear and linear circuit analysis, semiconductor physics, semiconductor devices and high-frequency engineering - are applied together for the development of communications application.

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Oral Examination</td><td>30-45 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr.-Ing. J. Christoph Scheytt</td></tr>
<tr><td>13</td><td>Other Notes:
<i>Remarks of course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:</i>
Course Homepage
https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/fast-integrated-circuits-for-wireline-communications/
Implementation
Lecture with Exercises (including computer-aided design using electronic design software)
Teaching Material, Literature
Handouts and literature references will be given in the lecture.
• E. Säckinger, “Broadband Circuits for Optical Fiber Communication”, Wiley, 2005
• B. Razavi, “Design of Integrated Circuits for Optical Communications”, McGraw-Hill, 2003
Comments
As part of the lecture a 2-day excursion to IHP Leibnizinstitute for High-Performance Microelectronics in Frankfurt (Oder) is offered which includes the visit of a modern chip fabrication facility (participation in the excursion is voluntary).</td></tr>
</table>

VLSI-Testing

VLSI-Testing

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92027	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92027 VLSI Testing	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course VLSI Testing:
Recommended: Digital Design

4 **Contents:**

Contents of the course VLSI Testing:
Short Description
The course “VLSI Testing” focuses on techniques for detecting hardware defects in microelectronic circuits. Algorithms for test data generation and test response evaluation as well as hardware structures for design for test (DFT) and on-chip test implementation (BIST) are presented.
Contents
In detail the following topics are covered:

- Fault models
- Testability measures and design for test (DFT)
- Logic and fault simulation
- Automatic test pattern generation (ATPG)
- Built-in self-test (BIST), in particular test data compression and test response compaction
- Memory test

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the students will be able

- to describe fault models, DFT techniques, and test tools,
- to explain and apply the underlying models and algorithms for fault simulation and test generation,
- to analyze systems with respect to their testability and to derive appropriate test strategies.

Key qualifications:
The students

- are able to apply the practiced strategies for problem solving across varying disciplines,
- have experience in presenting their solutions to their fellow students, and
- know how to improve their competences by private study.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4, Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Sybille Hellebrand

13	**Other Notes:** *Remarks of course VLSI Testing:* **Course Homepage** `https://ei.uni-paderborn.de/en/electrical-engineering/date/teaching/electrical-engineering/overview` **Implementation** • Lecture based on slide presentation, extensions on blackboard • Exercises in small groups based on exercise sheets with students presenting their own solutions • Hands-on exercises using various software tools **Teaching Material, Literature** Additional material can be found in panda • Michael L. Bushnell, Vishwani D. Agrawal, „Essentials of Electronic Testing for Digital, Memory, and Mixed-Signal VLSI Circuits,“Boston, Dordrecht, London: Kluwer Academic Publishers, 2000 • Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, „VLSI Test Principles and Architectures: Design for Testability,“ Morgan Kaufmann Series in Systems on Silicon, ISBN: 0123705975

3.6 Specialisation Area “Signal Processing”

Specialisation Area	Signal Processing
Modules	* Advanced System Theory * Digital Image Processing I * Digital Image Processing II * Digital Speech Signal Processing * Integrated Circuits for Wireless Communications * Optimal and Adaptive Filters * Fast Integrated Circuits for Wireline Communications * Statistical and Machine Learning * Cognitive Systems Engineering - Special Topics * Topics in Pattern Recognition and Machine Learning * Topics in Signal Processing * Wireless Communications
Catalogue advisor	Hellebrand, Sybille, Prof. Dr.
Credits ECTS	6
Learning objectives	

The modules from this specialisation area enable specialisation in the field of signal, image and language processing.

Advanced System Theory			
Advanced System Theory			
Module number: M.048.92001	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92001 Advanced System Theory	2L 2Ex, WS	60	120	C	60/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced System Theory:
Recommended:
Prerequisites are a basic understanding of differential equations, linear algebra, and Laplace transforms, as they are covered in a typical undergraduate course on system theory.

4 **Contents:**

Contents of the course Advanced System Theory:
Short Description
Building on an undergraduate system theory course, this course studies the dynamical behavior of linear systems with greater mathematical rigor. The course is primarily intended to serve students in engineering, but it can also be useful to students in physics and other natural sciences.
Contents

- System models and differential equations
- State-space and I/O descriptions
- Relations between internal and external descriptions
- Response of continuous- and discrete-time systems
- Stability, controllability, observability
- State-space realizations of external descriptions
- Feedback systems

5 **Learning outcomes and competences:**

After attending this course, students will be familiar with the most important concepts and results in linear system theory. Students will develop confidence in their ability to solve mathematical problems of analysis and design. Many of their timeless insights and intuitions about the dynamical behavior of systems will be drawn from this course. This course presents material broad enough so that students will have a clear understanding of the dynamical behavior of linear systems, including their power and limitations. This will allow students to apply the theory to other fields.

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Erdal Kayacan</td></tr>
<tr><td>13</td><td>Other Notes:
<i>Remarks of course Advanced System Theory:</i>
Course Homepage
https://en.ei.uni-paderborn.de/rat
Implementation
Lectures and exercises (including some computer simulations) Panda course for communication and material distribution
Teaching Material, Literature
Handouts and exercise / tutorial questions; literature references will be given in the first lecture</td></tr>
</table>

<table>
<tr><th colspan="4">Digital Image Processing I</th></tr>
<tr><td colspan="4">Digital Image Processing I</td></tr>
<tr><td>Module number:
M.048.92008</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
summer term</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
</table>

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92008 Digital Image Processing I	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Digital Image Processing I:
None. Basic programming knowledge is an advantage.

4 **Contents:**

Contents of the course Digital Image Processing I:

Short Description

This course provides a fundamental introduction to digital image processing. Upon successful completion, students will be able to thoroughly describe the basic concepts of image generation and representation. Additionally, they will acquire the skills to apply methods for enhancing and segmenting grayscale and color images in both the spatial and frequency domains, as well as techniques for image compression. Students will be capable of independently selecting, implementing, testing, and applying these techniques to complex image processing tasks. A typical application area is automation technology.

Contents

1. Introduction (Graphics File Formats, Application Examples, Human Vision) 2.Image Formation and Image Models (Camera Models, Image Formation, Image Sampling and Quantization)
2. Image Enhancement in the Spatial Domain (Gray-Level Transformation Functions, Histogram Processing, Spatial Filtering)
3. Image Enhancement in the Frequency Domain (2D Fourier Transform, Smoothing and Sharpening Filters, Implementation Details)
4. Color Image Processing (Color Spaces, Color and Pseudo-Color Image Processing, Spatial Filtering)
5. Image Compression and Reduction (Types of Redundancy, Compression Models, Lossless and Lossy Compression)

5 **Learning outcomes and competences:**

Domain competence

The students

- are able to describe the basics of image generation and image digitization and
- are able to select, implement, test and apply methods for the enhancement of images in the spatial and frequency domain, image segmentation and data reduction independently for complex image processing tasks.

Key qualifications

The students have a good command of programming in Python.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

none

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Markus Hennig
13	**Other Notes:** *Remarks of course Digital Image Processing I:* **Target group** Master's students in electrical engineering and related fields. **Course Homepage** `https://ei.uni-paderborn.de/get/teaching/dip-i` **Literature** • Gonzalez, R., & Woods, R. (2017). Digital Image Processing (4th Global Ed.). Pearson. Print ISBN: 978-1-292-22304-9, E-ISBN: 978-1-292-22307-0. • Mertsching, B. (2024). Digital Image Processing I (Lecture Notes). • Jähne, B. (2024). Digitale Bildverarbeitung (8th Edition, German Language). Springer. Print ISBN: 978-3-662-59509-1, E-ISBN: 978-3-662-59510-7. **Comment** The material presented in the lecture is implemented in the exercises using Python. The first exercise provides an introduction to this, so that it is possible to get started with limited programming knowledge. Regular and active participation in lectures and exercises is expected.

Digital Image Processing II			
Digital Image Processing II			
Module number: M.048.92010	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92010 Digital Image Processing II	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Digital Image Processing II:
Recommended:
Basic knowledge of image processing, (e. g. from the course Digital Image Processing I (L.048.23002 / L.048.92008)

4 **Contents:**

Contents of the course Digital Image Processing II:
Short Description
The course “Digital Image Processing II” is a module in the catalog “Cognitive Systems” for advanced students of the Electrical Engineering Master’s program and related degree programs. It follows the fundamental course “Digital Image Processing I” and covers methods for high-level image processing.
Contents
The following topics will be discussed during the semester:

- Image segmentation (line and edge detection, segmentation by region, superpixels)
- Feature extraction (feature descriptors, principal components, Scale-Invariant-Feature-Transform (SIFT))
- Stereo image analysis (depth perception, stereo geometry, correspondence problem)
- Motion (motion detection, optical flow, motion models, motion segmentation)
- Object recognition and image pattern classification (patterns, classifiers, neural networks and deep learning, convolutional neural networks (CNN))

After learning about the methods in the lecture, the students will implement them in Jupyter Notebooks.

5 **Learning outcomes and competences:**

Domain competence:
The students

- can apply methods for image segmentation, representation and description of features, stereo and motion image analyis, objection recognition and machine learning,
- are able to transfer the acquired knowledge of image processing to the processing of other multi-dimensional signals,
- are able to describe the state-of-the-art of the presented topics, and
- are able to implement the presented methods.

Key qualifications:
The students are able to identify and evaluate the function and the behavior of complex technical processes and their integration into the social environment while also considering ethical aspects.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Bärbel Mertsching

13	**Other Notes:** *Remarks of course Digital Image Processing II:* **Course Homepage** [http://getwww.uni-paderborn.de/teaching/dip-II] **Course Documents** see PANDA ([https://panda.uni-paderborn.de]) **References (excerpt)** • Mertsching, Bärbel: Digital Image Processing (lecture notes) • Forsyth, David and Ponce, Jean: Computer Vision - A Modern Approach. Prentice-Hall, 2nd ed., 2011. ASIN: B006V372KG • Gonzalez, Rafael C. and Woods, Richard E.: Digital Image Processing. Pearson Education Limited, 4th ed., 2018. ISBN-13: 978-1-292-22304-9 • Jähne, Bernd: Digitale Bildverarbeitung. Springer, 7. Aufl., 2012. ISBN-13: 978-3642049514

Digitale Sprachsignalverarbeitung			
Digital Speech Signal Processing			
Module number: M.048.24001	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.24001 Digital Speech Signal Processing	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Digitale Sprachsignalverarbeitung:
Recommended: Prior knowledge from the module Higher Mathematics.

4 **Contents:**

Contents of the course Digitale Sprachsignalverarbeitung:

Short Description

The course introduces the basic techniques and theories of digital speech signal processing. A focal point of the first part of the lecture is the topic “Listening and Speaking”, which is concerned with psychological effects of human sound perception and speech production. Subsequently, time discrete signals and systems, as well as computer based data processing are discussed. Further topics are non-parametric short-time analysis of speech signals, speech coding and IP-phones.

Contents

- Listen and talk
- Generating voice: human vocal tract, source filter model, vocoder
- Acoustic waves
- Listen: human ear, psycho acoustics and physiology of listening, loudness, acoustic occlusion, frequency groups
- Time-discrete signals and systems
- Basics: Elementary signals, LTI systems
- Transformations: Fourier transformation of time-discrete signals, DFT, FFT
- Time-discrete filtering in frequency domain: Overlap-Add, overlap-Save
- Statistical speech signal analysis
- Basics in theory of probabilities
- Short-run analysis of speech signals: Spectrogram, cepstrum
- Estimation of speech signals
- Optimal filters
- LPC analysis
- Spectral filtering for noise suppression: spectral subtraction, Wiener filter
- Adaptive Filters: LMS adaptation algorithm, echo compensation
- Speech coding
- Time domain coding: signal shape coding, parametric coding, hybride coding tech-niques
- Frequency domain coding
- Amplitude quantization: uniform quantization, quantization with companders (ulaw, alaw)

5 **Learning outcomes and competences:**

Domain competence:

After attending the course, the students will be able to

- analyze digital signals, e.g., audio signals, in the time or frequency domain,
- represent audio signals efficiently and
- implement widely-used algorithms for speech analysis and speech processing in the frequency or time domain.

Key qualifications:

The students

- are able to explain effects in real signals based on the theoretical knowledge,
- are able to investigate theoretical approaches by a systematic analysis and
- are, due to the precise treatment of the contents, in a position to continue their learning themselves

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Informatik v4, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr.-Ing. Jörg Schmalenströer</td></tr>
<tr><td>13</td><td>Other Notes:
<i>Remarks of course Digitale Sprachsignalverarbeitung:</i>
Course Homepage
https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/digital-speech-signal-processing
Implementation
• Lectures using the blackboard and presentations,
• Alternating theoretical and practical exercise classes with exercise sheets and computer and
• Demonstration of real technical systems in the lecture hall.
Teaching Material, Literature
Allocation of a script; information on textbooks ; matlab scripts</td></tr>
</table>

Integrierte Schaltungen für die drahtlose Kommunikation			
Integrated Circuits for Wireless Communications			
Module number: M.048.25017	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.25017 Integrated Circuits for Wireless Communications	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Integrierte Schaltungen für die drahtlose Kommunikation:
Recommended: Lecture Schaltungstechnik rsp. Circuit and System Design. Helpful supplement: Lecture “Wireless Communications” of Prof. Hab-Umbach.

4 **Contents:**

Contents of the course Integrierte Schaltungen für die drahtlose Kommunikation:
Short Description
Mobile communications, wireless networks, and RFID technology are application examples of wireless communications. Wireless communications has found widespread use in everyday life and will become even more important in the future. The design of electronic circuits for radio frequencies requires a good system knowledge with respect to typical transmitter and receiver architectures in wireless communications, components, and radio signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required. Goal of the lecture is to convey a methodical approach to the design of integrated circuits for wireless communications. A part of the exercises will pertain to calculation of circuit design problems another will be performed in small teams as a hands-on exercise using modern IC design software.
Contents
The lecture deals with analysis and design of radio frequency integrated circuits for wireless communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures “Schaltungstechnik” rsp. “Circuit and System Design”. The following topics will be addressed:

- Transmitter and receiver architectures for wireless communications
- System Theory Basics
  - Signals and noise
  - Modulation and demodulation
  - Transmission properties of wireless communcations systems
- Semiconductor technologies and integrated high-frequency devices
- Amplifiers (low-noise and variable-gain amplifiers)
- Mixers
- Oscillators
- Frequency synthesizer PLLs

5 **Learning outcomes and competences:**

The students will be able

- to describe architectures and circuits of wireless communication systems
- to describe and calculate fundamental signal transmission properties of wireless systems
- to apply design methods to design components of radio frequency ICs

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Oral Examination	30-45 min	100%

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr.-Ing. J. Christoph Scheytt
13	**Other Notes:** *Remarks of course Integrierte Schaltungen für die drahtlose Kommunikation:* **Course Homepage** `https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/integrierte-schaltungen-fuer-die-drahtlose-kommunikation/` **Implementation** • Lecture with Powerpoint presentation and handwritten mathematical derivations using tablet and beamer • Exercises partly as handwritten calculation exercises using tablet and beamer and partly as practical IC design exercises using IC design software **Teaching Material, Literature** Lecture slides and videos as well as exercise slides will be made available. • Behzad Razavi “RF Microelectronics”, Prentice Hall, 2011 • Thomas Lee “The Design of CMOS Radio-Frequency Integrated Circuits”, Cambridge University Press 2003

Optimale und Adaptive Filter			
Optimal and Adaptive Filters			
Module number: M.048.24010	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.24010 Optimal and Adaptive Filters	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optimale und Adaptive Filter:
Recommended: Prior knowledge from the modules Higher Mathematics and Digital Signal Processing.

4	**Contents:** *Contents of the course Optimale und Adaptive Filter:* **Short Description** The course “Optimal and adaptive filters” gives an introduction to the basic techniques and theories of adaptive filters. Based upon the basics of estimation theory optimal filters are discussed. Subsequently the topics Wiener filter theory, deterministic optimization under constraints and stochastic gradient methods are regarded. Concluding the Least Squares approach for solving filter tasks and the Kalman filter are introduced. The latter is regarded as a brief introduction to state based filters. **Contents** • Classic parameter estimation • Estimators • MMSE-Estimation • Linear estimators • Orthogonality principle • Evaluation of estimators • Wiener filter • Wiener-Hopf equation • AR- and MA processes • Linear prediction • Iterative optimization methods • Gradient ascent/descent • Newton method • Linear adaptive filters • LMS algorithm • Least-Squares method • Blockwise and recursive adaptiv filters • Realization aspects • Statemodel based filters • Kalman filter • Applications • System identification • Channel estimation and equalization • Multi-channel speech signal processing • Noise and interference suppression

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the students will be able to

- analyze task on the field of adaptive filters and to formulate requirements mathematically,
- develop filter using cost functions and
- implement selected adaptive filters in the frequency or time domain.

Key qualifications:
The students

- are able to check theoretical results using practical realizations,
- are able to undertake theoretical approaches a systematic analysis using methodical procedures and
- are, due to the precise treatment of the contents, in a position to continue their learning themselves.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12 **Module coordinator:**

Dr.-Ing. Jörg Schmalenströer

13	**Other Notes:** *Remarks of course Optimale und Adaptive Filter:* **Course Homepage** `https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/optimal-and-adaptive-filter` **Implementation** • Lectures using the blackboard and presentations, • Alternating theoretical and practical exercises classes with exercise sheets and computer and • Demonstration of real technical systems in the lecture hall. **Teaching Material, Literature** Allocation of a script; information on textbooks; matlab scripts

Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation

Fast Integrated Circuits for Wireline Communications

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.25019	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de / en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.25019 Fast Integrated Circuits for Wireline Communications	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:
Recommended: Module “Schaltungstechnik” of the Bachelor Electrical Engineering or module “Circuit and System Design” of the Master “Electrical Systems Engineering” or comparable modules / lectures

4	**Contents:** *Contents of the course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:* **Short Description** Nowadays commercial fiber-optic communication systems reach very high data rates of 100 Gb/s per optical channel and several Tb/s in a single fiber. In a similar way very high data rates of more than 10 Gb/s occur at a single package pin of electronic chips. These signals are to be transmitted over printed circuit boards and inexpensive serial cables. In the future the progress of CMOS technology and communication technology will push speed of fiber-optic and wire-line communication continuously to ever higher data rates. The design of electronic circuits for high bandwidth rsp. data rates requires a good system knowledge with respect to typical transmitter and receiver architectures, components, and signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required. Goal of the lecture is to enable the student to utilize a methodological approach for the design of fast integrated electronic circuits for digital wired communications. A part of the exercises will be carried out using modern industry-standard IC design software. **Contents** The lecture deals with analysis and design of fast integrated electronic circuits for digital broadband communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures “Schaltungstechnik” rsp. “Circuit and System Design”. The lecture deals with: • Transmitter and receiver architectures for fiber-optic communications • Transmitter and receiver architectrues for chip-to-chip communications • System design • Semiconductor technology and integrated high-frequency devices • Broadband amplifiers • Current-mode logic • Transmitter and receiver circuits • PLLs for frequency synthesis and clock recovery • Measurement methods
5	**Learning outcomes and competences:** **Domain competence:** The student will be able to: • describe and analyze transmitter and receiver architectures for broadband communication links • understand and describe semiconductor technologies and integrated high-frequency devices for broadband circuits • to analyze circuit design techniques for transmitter and receiver circuits and describe ways to optimize them • to describe circuits in PLL technique for frequency synthesis and clock recovery • to describe measurement methods **Key qualifications:** The students will learn how different interdisciplinary scientific domains and their methods - like mathematical signal and system analysis, non-linear and linear circuit analysis, semiconductor physics, semiconductor devices and high-frequency engineering - are applied together for the development of communications application.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Oral Examination	30-45 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12 **Module coordinator:**

Prof. Dr.-Ing. J. Christoph Scheytt

13 **Other Notes:**

Remarks of course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:
Course Homepage
`https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/fast-integrated-circuits-for-wireline-communications/`
Implementation
Lecture with Exercises (including computer-aided design using electronic design software)
Teaching Material, Literature
Handouts and literature references will be given in the lecture.

- E. Säckinger, “Broadband Circuits for Optical Fiber Communication”, Wiley, 2005
- B. Razavi, “Design of Integrated Circuits for Optical Communications”, McGraw-Hill, 2003

Comments
As part of the lecture a 2-day excursion to IHP Leibnizinstitute for High-Performance Microelectronics in Frankfurt (Oder) is offered which includes the visit of a modern chip fabrication facility (participation in the excursion is voluntary).

Statistical and Machine Learning

Statistical and Machine Learning

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.23012	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.23012 Statistical and Machine Learning	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Statistical and Machine Learning:
Recommended: Elementary knowledge in probability theory, as is taught in the course Statistical Signal Processing. Basic programming skills are desirable.

4 **Contents:**

Contents of the course Statistical and Machine Learning:
Short Description
The course on Statistical and Machine Learning presents an introduction into the components and algorithms prevalent in statistical and machine learning. Modern techniques will be presented for gleaning information from data. Both supervised and unsupervised learning algorithms will be discussed. The presented techniques can be applied to a variety of classification and regression problems, both for one-dimensional input data (e.g., speech), two-dimensional (e.g., image) or symbolic input data (e.g., documents).
Contents
Introduction to classification problems, Bayesian and other decision rules Optimization: gradient descent, algorithmic differentiation, optimization with constraints *Linear classifiers, Support Vector Machines* Deep neural networks (deep learning) *Dimensionality reduction (PCA, LDA)* Unsupervised learning (mixture densities, clustering techniques)

5 **Learning outcomes and competences:**

Domain competence:
After completion of the module students will be able to

- Find an appropriate approach to solving a given classification or regression problem
- Apply supervised or unsupervised learning techniques to data of various kinds and critically assess the outcome of the learning algorithms
- Can appreciate the power and limitations of machine learning algorithms
- Work with software for solving machine learning problems and write own software components, apply them to given data sets and optimize parameter settings
- Find, for a given training set size, an appropriate choice of classifier complexity und feature vector dimensionality

Key qualifications:
The students

- Have gathered sufficient proficiency in Python, which is valuable well beyond this course
- Can assess the importance of the principle of parsimony and are able to transfer it to other
- Are able to analyse a given classification or regression problem, synthesize a solution, and evaluate the performance on test data
- Are able to apply the knowledge and skills learnt in this course to a wide range of disciplines
- Can work cooperatively in a team and subdivide an overall task into manageable subtasks and work packages
- Acquired a general understanding of the power and limitations of machine learning algorithms

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Reinhold Häb-Umbach
13	**Other Notes:** *Remarks of course Statistical and Machine Learning:* **Course Homepage** `https://ei.uni-paderborn.de/en/statistical-and-machine-learning` **Implementation** *Lectures predominantly using the blackboard or overhead projector, occasional presentations of (powerpoint) slides ,* Exercise classes with exercise sheets and demonstrations on computer *Implementation of learning and classification algorithms on a computer by the students themselves; use of algorithms on real-world data or data generated on the computer, evaluation of the simulation results **Teaching Material, Literature** Course script and summary slides are provided to the students. Exercises and solutions to exercises, as well as sample implementations of algorithms are provided to the students *R.O. Duda, P.E. Hart, D.G.~ Stork, Pattern Classification, Wiley, 2001* I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016 *S. Theodoridis: Machine Learning, Academic Press, 2015* K. Fukunaga, Introduction to Statistical Pattern Recognition, Academic Press, 1990

Technische kognitive Systeme - Ausgewählte Kapitel			
Cognitive Systems Engineering - Special Topics			
Module number: M.048.23019	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer- / winter term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.23019 Cognitive Systems Engineering - Special Topics	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

two out of three topics, see point 4

3 **Admission requirements:**

None

Prerequisites of course Technische kognitive Systeme - Ausgewählte Kapitel:
Recommended: Interest in the subject-matter and interdisciplinary work.

4	**Contents:** This module is offered in three parts. Students have to choose **two out of three**. Each part lasts two hours per week. *Contents of the course Technische kognitive Systeme - Ausgewählte Kapitel:* **Part A** At any given time, the sensory receptors of living beings are exposed to a very large amount of information, of which only a small proportion can be consciously processed. Visual attention is understood as the pooling of available cognitive resources for optimal processing of visual stimuli. The seminar introduces the modeling and experimental investigation of visual attention and the transfer to intelligent technical systems. It will be shown how research can be conducted jointly across disciplinary boundaries. The current focus is on the topic of saliency. The course always takes place in the winter semester. **Part B** While "sensation" describes the signals from the physical world that reach our sensory receptors, "perception" refers to the processes by which our brain selects, organizes, and interprets the signals. This seminar provides students in technical courses with an overview of the fundamentals of biological sensory systems and perception. In addition to the exciting and (sometimes non-intuitive) background of these topics, there will be a critical discussion of the transferability of biological concepts and mechanisms to technical systems. This seminar is always in the summer semester. **Part C** In this seminar, current interim reports and results from ongoing bachelor's and master's theses, research projects, and third-party funded projects from the GETLab - Technical Cognitive Systems department will be presented. Furthermore, there will be presentations by guests of the research group. The seminar is offered in the summer and winter semester.
5	**Learning outcomes and competences:** **Domain competence:** The students • are able to name basic research topics related to the design and the implementation of technical cognitive systems, • can apply and evaluate technical cognitive systems, and • are able to understand, design, implement and evaluate basic psychophysical experiments. **Key qualifications:** The students • are able to research and evaluate technical literature, • have developed an understanding of the discipline-related research approaches (computer science, electrical engineering, psychology) and • are able to carefully consider the potential use of bio-inspired mechanisms in technical systems.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Bärbel Mertsching
13	**Other Notes:** **Module Homepage** [http://getwww.uni-paderborn.de/teaching/cse] **Teaching Material, Literature** Literature references will be given at the first dates of the seminar. *Remarks of course Technische kognitive Systeme - Ausgewählte Kapitel:* --- **ATTENTION - IMPORTANT NOTICE** The course doesn’t take place in winter term 2024/25. Please see the notice boards of the group. ---

Topics in Pattern Recognition and Machine Learning			
Topics in Pattern Recognition and Machine Learning			
Module number: M.048.92030	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92030 Topics in Pattern Recognition and Machine Learning	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Topics in Pattern Recognition and Machine Learning:
Recommended: Elementary knowledge in Probability Theory, as is taught in the module Statistical Signal Processing. Desirable, but not mandatory: knowledge in the field of statistical and machine learning; basic programming skills

4

Contents:

Contents of the course Topics in Pattern Recognition and Machine Learning:
Short Description
The course on Topics in Pattern Recognition and Machine Learning first briefly summarizes the main concepts of statistical pattern recognition and machine learning. Next selected topics will be presented in detail. The choice of topics depends on current research activities and thus may change over time. Examples of such topics to be studied in detail include

- Deep Learning
- Model estimation in the presence of hidden variables, in order to reveal suspected latent structure buried in the data
- Bias-Variance dilemma and the tradeoff between degree of detail and generalizability of models
- Grafical models
- Sequential data and hidden Markov models
- Decision trees, model combination
- Specific classification tasks, such as automatic speech recognition While the first part of the course will follow a regular lecture format, the second part will include active student participation. Students will be asked to read, analyze and present recently published papers from the pattern recognition and machine learning literature. This will often also include the implementation of proposed algorithms in Matlab.

Contents

- Fundamentals of statistical pattern recognition: Bayes rule, learning of class-conditional densities, linear models for classification and regression
- Deep neural networks: MLP, CNN, RNN and others
- EM Algorithm and extensions thereof
- Models with discrete or continuous latent variables; GMM, NMF
- Bias-Variance dilemma and model selection
- Graphical models
- Hidden Markov models and their application in speech recognition
- Decision trees, model combination
- Recent publications in pattern recognition and machine learning

5

Learning outcomes and competences:

Domain competence:
After completion of the course students will be able to * Choose an appropriate classifier for a given classification problem and be able to learn the parameters of the classifier from training data

- Choose an appropriate regression method for function approximation and learn its parameters from training data
- Search for latent variables and structure in given data
- Make an informative choice for the model order to find a good compromise between degree of detail and generalizabliliy
- Comprehend and analyze recent publications from the field of pattern recognition and machine learning

Key qualifications:
The students

- Have gathered an understanding of the importance of the chosen model order on the outcome of classification and regression tasks
- Are aware of the impact of a priori assumptions on the result of latent variable and structure discovery in data
- Are able to autonomously gain expertise in a certain field of pattern recognition by conducting a literature survey
- Can gauge the importance of a given publication for the state of the art in a field
- Are able to apply the knowledge and skills learnt in this course to a wide range of disciplines

6

Assessments:

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7

Study Achievement:

none

8

Prerequisites for participation in examinations:

None

9

Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.

10

Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).

<table>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master’s Program Electrical Systems Engineering (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Reinhold Häb-Umbach</td></tr>
<tr><td>13</td><td>Other Notes:
<i>Remarks of course Topics in Pattern Recognition and Machine Learning:</i>
Course Homepage
<code>https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/topics-in-pattern-recognition-and-maschine-learning</code>
Implementation
Lectures predominantly using the blackboard or overhead projector, occasional presentations of (powerpoint) slides ,
Exercise classes with exercise sheets and demonstrations on computer
Instructions how to read and analyze scientific publications in this field Autonomous analysis of publications and presentation of results and gained insight
Teaching Material, Literature
R.O. Duda, P.E. Hart, D.G.~ Stork, Pattern Classification, Wiley, 2001
I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, MIT Press, 2016
C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006</td></tr>
</table>

Topics in Signal Processing			
Topics in Signal Processing			
Module number: M.048.92014	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92014 Topics in Signal Processing	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Topics in Signal Processing:
Recommended: Signal and system theory, at least a basic understanding of probability and linear algebra

4 **Contents:**

Contents of the course Topics in Signal Processing:
Short Description
This course covers a selection of current topics in signal processing. One part of this course will follow a regular lecture format, while the other part will require active student participation.
Contents
This course will first review relevant aspects of linear algebra and probability theory. Then students will learn how to read, analyze, and present recent papers from the signal processing literature.

5 **Learning outcomes and competences:**

In this course, students will familiarize themselves with some current research topics in signal processing. They will learn to read and understand scientific publications and to critically evaluate results. Students will develop confidence in their ability to solve mathematical problems of analysis and design. They will be able to apply the principles they have learnt in this course to other areas.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Peter Schreier
13	**Other Notes:** *Remarks of course Topics in Signal Processing:* **Course Homepage** `http://sst.uni-paderborn.de/teaching/courses/` **Implementation** Lectures and tutorials with active student participation, student presentations **Teaching Material, Literature** References will be given in the first lecture.

<table>
<tr><th colspan="4">Wireless Communications</th></tr>
<tr><td colspan="4">Wireless Communications</td></tr>
<tr><td>Module number:
M.048.92035</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
summer term</td></tr>
<tr><td>Language:
de / en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
</table>

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92035 Wireless Communications	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Wireless Communications:
Recommended: Some basic knowledge in digital communication systems.

4 **Contents:**

Contents of the course Wireless Communications:
The course provides students with an insight into the techniques for reliable communication via time and/or frequency selective radio channels. To this end, the physical and statistical modeling of the radio channel is first presented, which forms the basis for understanding the transmission methods adapted to these channel conditions. Then, the main transmission and reception principles are presented, in particular the different diversity schemes:

- Time diversity: maximum ratio combiner, error rate calculation for coherent and incoherent reception, interleaving.
- Antenna diversity: SIMO, MISO and MIMO techniques
- Frequency diversity for frequency selective channels: Single-carrier techniques with sequence detection, band-spreading techniques, multicarrier transmission.

Emphasis will be placed on an illustrative derivation of the receiver principles as operations in a linear vector space. In addition, an insight into current cellular radio communication systems is given.
Table of contents

- Pulse amplitude modulation and orthogonal multi-pulse modulation
- Optimal detection
- Channel models for mobile radio
- Treatment of intersymbol interference
- Error rate on frequency nonselective Rayleigh Fading channel
- Diversity schemes: time, space, and frequency diversity
- Channel coding
- Cellular systems

5 **Learning outcomes and competences:**

Domain competence:
After completion of the course students will be able to

- Develop a discrete-time statistical channel model for a given physical description of a wireless communication channel
- Explain the techniques and algorithms used in the Physical Layer of a wireless communication system
- Understand the fundamental design options and decisions taken to realize reliable communication over time variant and frequency selective or nonselective fading channel
- Appreciate and categorize the techniques used in modern cellular communication systems to realize reliable communication
- Trade off the advantages and disadvantages of different transmission techniques with respect to bandwidth and power efficiency as well as number of users to be served
- Select and design an appropriate transmission technique for a wireless channel
- Simulate and analyze simple communication systems using modern software tools

Key qualifications:
The students

- Can transfer and apply the concept of linear vector spaces to signal processing tasks other than for wireless communications
- Can apply the skills about the generation of data, simulation of systems and analysis of experimental results using modern software tools, that have been acquired in this course, to other disciplines
- Can work cooperatively in a team and subdivide an overall task into manageable subtasks and work packages

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Häb-Umbach
13	**Other Notes:** *Remarks of course Wireless Communications:* **Course Homepage** `https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/wireless-communications` Course script and summary slides are provided to the students. Exercises and solutions to exercises, as well as sample implementations of algorithms are provided to the students • Häb-Umbach, Reinhold: Wireless Communications (Lecture notes) • D. Tse: Fundamentals of Wireless Communications, Cambridge University Press, 2006 • K.D. Kammeyer: Nachrichtenuübertragung, Teubner, 2004 • P. Höher: Grundlagen der digitalen Informationsübertragung, Springer/Vieweg 2013

4 General Elective Area

4.1 EE Catalogue Energy and Environment

Bauelemente der Leistungselektronik			
Power Electronic Devices			
Module number: M.048.22003	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.22003 Power Electronic Devices		60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Bauelemente der Leistungselektronik:
Recommended: Knowledge from lecture Power Electronics is desirable.

4 **Contents:**

Contents of the course Bauelemente der Leistungselektronik:
Short Description
The course covers power electronic devices, snubber circuits, driving and cooling. Another topic is the design of magnetic components and fast current sensors.
Contents

- power electronic devices: Diodes, BJT, GTO, MOSFET, IGBT
- snubbers, driving and protection of semiconductor switches; cooling systems
- magnetic materials, test circuit for core losses, winding patterns
- concept of integrated magnetics
- electromechanical design and modelling of uncoupled, linear coupled, nonlinear coils and SMPS transformers
- capacitors
- filters
- dynamic current sensing

5 **Learning outcomes and competences:**

Professional Competence
After attending the course, the students will be able

- to choose suitable power semiconductors, magnetic materials and core forms
- to select and dimension snubber circuits, current sensors and drivers for power semiconductors
- to design magnetic components and power filters

(Soft) Skills
The students

- learn to describe real components with an equivalent circuit
- improve their skills in computer aided circuit design
- extend their competence by self study

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Dr.-Ing. Frank Schafmeister
13	**Other Notes:** *Remarks of course Bauelemente der Leistungselektronik:* **Course Homepage** `http://wwwlea.upb.de` **Implementation** *lecture* exercise **Teaching Material, Literature** Lecture slides and notes, further literatur will be announced in lecture.

Datengetriebenes Ressourcenmanagement			
Data-driven Resource Management			
Module number: M.104.7420	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de	**Semester number:** 1.-3.	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.104.61230 Data-driven Resource Management	L1 S2 Ex1	60	120	C	30

2 **Options within the module:**

None

3 **Admission requirements:**

None

4 **Contents:**

Contents of the course Datengetriebenes Ressourcenmanagement (ET):
In this course, students work together with lecturers to develop interdisciplinary solutions for the interfaces between the topics of IIOT (Industrial Internet of Things) and resource management. The objectives are, for example, the use of industrial processes and energy storage systems to shift energy flows over time (supporting the energy transition) and increasing internal resource and energy efficiency. The thematic focus is on energy and material requirements in industry. There are already a number of technical approaches to this, which will be improved or combined within the event. Basic components of the course (varies depending on the semester assignment):

- Fundamentals of resource management and efficiency
- Fundamentals of energy management and efficiency, decentralized energy supply in industry, potentials of energy storage
- Measuring technology
- Fundamentals of data management
- Management of product data and product life cycle
- Finding creative solutions
- Presentation of the issues
- Carrying out project planning as a group

5	**Learning outcomes and competences:** Firstly, students acquire the necessary specialised knowledge (see contents). Subsequently, problems are formulated together or specified by the lecturer. The students develop solutions (preferably in groups) to increase sustainability in production or the factory. This can be, for example, a technical (possibly patentable) solution, a prototype for a product, a business idea for a spin-off or an in-depth study. The procedure promotes communication skills as well as teamwork and the ability to reflect.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Univ.-Prof. Dr.-Ing. Alexander Schlüter
13	**Other Notes:** None *Remarks of course Datengetriebenes Ressourcenmanagement (ET):* The assignments should be held in blocks by mutual agreement.

Assessments (row 6):

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Presentation	30 min.	100%

Circular Economy and Energy			
Circular Economy and Energy			
Module number: M.104.7422	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de	**Semester number:** 1.-3.	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.104.61240 Circular Economy and Energy		60	120		30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Circular Economy and Energy (ET):
none

4 **Contents:**

Contents of the course Circular Economy and Energy (ET):
The contents of this module revolve around the interdisciplinary development of circular economy (CE) solutions in the field of energy. The subtopics of the semester will be announced on the department's homepage (go.upb.de/NIWI_1) no later than the start of registration. Examples could be: CE for batteries, CE for transformers, CE for Photovoltaic systems. The basic components are:

- Basics of Circular economy
- Energy systems and its components
- Assignments on circular economy in the selected subtopics of the energy branch
- Semester-specific subtopic of CE in the energy field
- Elaboration of the problem or need
- Carrying out project planning
- Feedback and optimization

5 **Learning outcomes and competences:**

Students acquire specialist knowledge on the subtopic of the semester (see contents). For this purpose, problems are formulated together or given by the lecturer. The students develop solutions for a more sustainable coexistence or a more sustainable economy. This can e.g. be a technical (possibly patent-worthy) solution, a prototype for a product, a business idea for a spin-off or even an in-depth job. The approach promotes communicative skills as well as the ability to work in a team and reflect on solutions for a specific CE approach.

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Presentation</td><td>30 min.</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4</td></tr>
<tr><td>12</td><td>Module coordinator:
Univ.-Prof. Dr.-Ing. Alexander Schlüter</td></tr>
<tr><td>13</td><td>Other Notes:
None
<i>Remarks of course Circular Economy and Energy (ET):</i>
The assignments should be held in blocks by mutual agreement.</td></tr>
</table>

Design of Energy Transition Scenarios			
Design of Energy Transition Scenarios			
Module number: M.048.22020	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.22020 Design of Energy Transition Scenarios	2L, 2EX, WS	60	120	P	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Design of Energy Transition Scenarios:
None

4 **Contents:**

Contents of the course Design of Energy Transition Scenarios:
Building on a fundamental understanding of energy systems, the course covers the basics of designing energy transition scenarios. To this end, integrated energy systems and, in particular, concepts of sector coupling are first repeated. In addition, the basics of scenario techniques in the context of the energy transition are introduced. On this basis, common concepts of modelling and simulation of energy systems are dealt with and common simulation software is introduced. The theory is deepened using practical examples and open source solutions for energy system planning. Energy transition scenarios are developed, calculated and evaluated from scratch for selected regions.

5 **Learning outcomes and competences:**

By participating in the course, students will be able to design energy transition scenarios and calculate and evaluate them using common simulation software. Basic concepts of sector coupling as well as techniques for scenario building and energy system planning are learnt and can be applied.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik

12 **Module coordinator:**

Prof. Dr. Henning Meschede

13 **Other Notes:**

none

Energiesystemtechnik			
Energy System Technologies			
Module number: M.048.22018	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.22018 Energy System Technologies	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Energiesystemtechnik:
None

4 **Contents:**

Contents of the course Energiesystemtechnik:
The field of energy system technologies includes the holistic consideration of thermal, electrical and chemical energy systems, consisting of the provision of useful energy, energy distribution and energy demand. In this course the basics of energy systems are taught. Based on the descriptions of the essential individual components, the interaction of these components is analyzed with regard to the coverage of the energy demand. Accordingly, aspects of sector coupling as well as storage technologies are introduced as components of energy systems. In addition to the technical description and design of energy systems, ecological and economic aspects for the holistic evaluation of energy systems are presented.

5 **Learning outcomes and competences:**

Students can assess energy systems holistically, in particular they can analyze and design energy systems in terms of energy demand. They know the individual components and are able to design them both technically and to evaluate the interactions in the context of the overall system as well as in meaningful subsystems. Students are able to quantify energy systems using energy, ecological and economic indicators. They know aspects of renewable energies, energy storage and sector coupling and can apply these to questions of sustainable energy systems.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Prof. Dr. Henning Meschede
13	**Other Notes:** none

Energy Transition			
Energy Transition			
Module number: M.048.22014	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.22014 Energy Transition	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Energy Transition:
None

4 **Contents:**

Contents of the course Energy Transition:
Short Description
With dependency and the long-term depletion of fossil energy resources such as coal, oil, gas, the increasing climate crises, and the shut-down of the nuclear programs in many countries, the necessity to set-up an energy structure based on renewable energies with often fluctuating power output is a vast challenge for electrical engineering. This lecture faces that challenge explaining the functioning and performance parameters of all types of renewable energy conversion devices, their availability, interaction and adaptability to load structures. Vice versa, the adaptability of load curves to the availability of the energy sources shall be presented, including new concepts, e.g. decentralized generation, storage and energy management, in particular Demand-Side-Management, P2X.
Contents

1. Existing energy structures: History, development
2. Present components & systems: generation, transport, consumption
3. Characteristics of variable renewable energy sources: solar thermal, photovoltaics, wind power
4. Characteristics of renewable energy sources: hydro & wind power
5. Characteristics of steady renewable energy sources: biomass, geothermal energy
6. Individual and combined availability and performance
7. Energy management, transport (smart grid) and storage necessities
8. Storage devices and concepts: types, performance, costs
9. New concepts to minimize costs: decentralized, autonomous and semi-autonomous systems, swarm concepts, demand side management, (DSM), power to gas & heat (P2X)
10. Geographical differences: Local resources, potentials, load structures
11. Legislative issues: access to grid & electricity spot-market
12. Excursion to practical project examples

5 **Learning outcomes and competences:**

Domain competence:
After completing the course the students should in a position to: understand the implications, necessities and properties of an energy supply system (energy system 2.0) based on the combination of different renewable energy sources, distribution, storage, demand side management and be familiarized with the components, its specific characteristics and parameters.
Key qualifications:
The students

- are enabled to apply the knowledge and skills across disciplines
- are enabled to use method-oriented approaches for the implementation of sustainable energy supply
- are enabled to educate themselves in the future

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written Examination	120-180 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Prof. Dr.-Ing. Stefan Krauter
13	**Other Notes:** *Remarks of course Energy Transition:* **Course Homepage** https://panda.uni-paderborn.de/course/view.php?id=40584 `http://www.nek.upb.de/lehre` **Implementation** Lecture combined with practical examples & simulations; Excursion to see applications in practice. **Teaching Material, Literature** All presentations and exercises plus additional resources are available on PANDA Playlist for the videos of the lecture: https://youtube.com/playlist?list=PLpgi7D_IhqlrD37mBky0fSoKb9hvfutE9 Literature *Stephen W. Fardo, Dale R. Patrick: Electrical Power Systems Technology. The Fairmont Press, Inc., 2009.* Michel Crappe: Electric Power Systems. John Wiley & Sons, 2008. *Magdi S. Mahmoud: Decentralized Systems with Design Constraints. Springer: Berlin Heidelberg, New York, 2011.* Hermann Scheer, The Energy Imperative, 100 Percent Renewable Now. Routledge, 2011. *Hermann Scheer: Energy Autonomy. Earthscan/James & James, 2006.* Geert Verbong, Derk Loorbach: Governing the Energy Transition - Reality, Illusion or Necessity?, Routledge, 2012 *Fraunhofer ISE: Actual Facts for PV https://www.ise.fraunhofer.de/de/veroeffentlichungen/studien/aktuelle-fakten-zur-photovoltaik-in-deutschland.html* Solar Power Europe, PV Outlook 2022-26: https://www.solarpowereurope.org/insights/market-outlooks/global-market-outlook-for-solar-power-2022 *Journals: Renewable Energy, Elsevier; IEEE Transactions on Power Systems **Comments** Excursion to a practical project (e.g., pumped hydro storage (PHS))

Intelligent Control of Electricity Grids

Intelligent Control of Electricity Grids

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.22002	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.22002 Intelligent Control of Electricity Grids	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Intelligent Control of Electricity Grids:
None

4 **Contents:**

Contents of the course Intelligent Control of Electricity Grids:
Dynamic properties of important energy converters also and especially in interaction with the grid. Classical control of island and interconnected grids as well as *Future requirement profiles for automated grid control with decentralized feeders.* Optimal economic load distribution *Descriptions of networks for use in automated network control centers.* Estimation of system states using linear and nonlinear methods (State Estimation). *Estimation of system states based on measurements:* Possibilities to detect and eliminate grossly incorrect measurement errors. *special questions in the environment of the topic

5 **Learning outcomes and competences:**

Specialized competence:

- In this module, students learn about the problems of today's and the objectives and requirements of future automated power supply systems. For this purpose, special, representative questions are used as examples, with which important problems of future grids can also be discussed.
- Current events in and around the "automation of electrical grids" will be discussed as a matter of course in order to assess the course content.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Fette, Michael, Dr. –Ing. habil.
13	**Other Notes:** none

Leistungselektronik

Power Electronics

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.22006	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de / en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.22006 Power Electronics	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Leistungselektronik:
None

4 **Contents:**

Contents of the course Leistungselektronik:
Short Description
The task of power electronics is the conversion between various kinds of electrical energy by means of electronic circuits. The lecture introduces the modern power electronic principles and their tasks. The basic power electronic circuits are introduced and analyzed. Typical application examples from the fields of industry, energy and transportation are discussed.
Contents

- Modeling power electronic circuits as idealized switching networks
- Basic circuits of self-commutated converters: Buck and boost converters
- Basic circuits of line- and load-commutated converters
- Commutation, snubber circuits
- State-Space averaging
- Pulse width modulation, current and voltage ripples, harmonics
- Application examples from railway, automotive, industry, and energy generation and distribution

5 **Learning outcomes and competences:**

Domain competence:

- Understanding the modern principles of electrical energy conversion
- Competence to evaluate, select and design power electronic circuits

Key qualifications:
The students

- learn to transfer the learned skills also to other disciplines,
- extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises,
- learn strategies to acquire knowledge from literature and internet.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5

12 **Module coordinator:**

Dr.-Ing. Frank Schafmeister

13 **Other Notes:**

Remarks of course Leistungselektronik:
Course Homepage
`http://wwwlea.upb.de`
Implementation

- Lecture using blackboard as well as prepared slides
- Exercises within the group
- Exercises in the computer room

Teaching Material, Literature
Lecture notes, slides. Other literature will be given in the lecture

- J. Böcker: Skript/lecture notes: Leistungselektronik
- D. Schröder: Elektrische Antriebe, Band 4: Leistungselektronische Schaltungen, Springer, 1998
- N. Mohan, T. Undeland, W. Robbins: Power Electronics - Converters, Applications and Design, John Wiley & Sons, Inc., 2. Edition, 2001
- R. Erickson, D. Maksimovic: Fundamentals of Power Electronics, Kluver Academic Publishers, 2. Edition, 2001

Leistungselektronik für die Energiewende			
Power Electronics for the Energy Transistion			
Module number: M.048.22017	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.22017 Power Electronics for the Energy Transistion	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Leistungselektronik für die Energiewende:
Recommended: It is recommended to take part also in the lecture power electronics, however, this is not mandatory

4 **Contents:**

Contents of the course Leistungselektronik für die Energiewende:

- Brief introduction to power electronics
- Economic fundamentals of the energy industry, rules, EEG law, electricity stock exchange, etc.
- Technical principles of the energy industry, average demand, daily and seasonal fluctuations, etc.
- AC transmission and distribution grids, transformers, basics of control active and reactive power, minute reserve, primary, secondary and tertiary control
- Flexible AC transmission systems (FACTS)
- Static reactive power compensator (STATCOM), passive and active filters, electronic transformers
- Sector coupling, Power to Gas, Vehicle to Grid, E-mobility
- Photovoltaic inverter
- Wind power converter
- Uninterruptible power supplies
- Battery storage and converters and energy management
- Smart grids
- DC grids
- High-voltage DC transmission

5	**Learning outcomes and competences:** • Understanding of energy systems, interactions and necessary technologies • Ability to analyse and evaluate such systems • First competences for the selection and design of individual components
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Dr.-Ing. Frank Schafmeister

Assessments (item 6):

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

13	**Other Notes:** **Module Homepage** `https://ei.uni-paderborn.de/lea/lehre/veranstaltungen/lehrangebote/` **ATTENTION - IMPORTANT NOTICE** The course doesn’t take place in summer term 2024. *Remarks of course Leistungselektronik für die Energiewende:* **ATTENTION - IMPORTANT NOTICE** The course doesn’t take place from summer term 2024 until further notice.

Leistungselektronische Stromversorgungen			
Switched mode power supplies			
Module number: M.048.22016	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.22016 Switched Mode Power Supplies	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Leistungselektronische Stromversorgungen:
None

4 **Contents:**

Contents of the course Leistungselektronische Stromversorgungen:
Short Description
The course covers basic circuit topologies of electronic power supplies with electric isolation as well as their modeling and control.
Contents

- Basic circuits of isolated DC-DC power converters
- Transformers, coupled inductors, filters and resonant tanks
- Resonant technique for low loss switching
- Control design for switched mode power supplies
- Rectifiers with sinusoidal current shape (PFC): power stage and control concepts

5	**Learning outcomes and competences:** **Domain competence:** After attending the course, the students will be able • to analyse power electronic circuits according to their mode of operation and component requirements • to compare technologies and switching techniques and to evaluate their ability for specific applications • to model circuit and control by special procedures **Key qualifications:** The students • learn a circuit related view and the ability to define component requirements • improve their skills in computer-based circuit- and control modelling • extend their competence by self study; a one-day practical course will be offered therefore
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination	120-180 min or 30-45 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Dr.-Ing. Frank Schafmeister

13	**Other Notes:** *Remarks of course Leistungselektronische Stromversorgungen:* **Course Homepage** `http://wwwlea.upb.de` **Implementation** • lecture • exercise (classic exercise and computer-based simulation) • one-day practical course in the last week of lecture period (assembly and initial operation of a switched mode power supply) **Teaching Material, Literature** Lecture slides and skript, further literature will be announced within the lecture.

Mensch-Haus-Umwelt			
Men-House-Environment			
Module number: M.048.22007	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.22007 Men-House-Environment	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Mensch-Haus-Umwelt:
None

4 **Contents:**

Contents of the course Mensch-Haus-Umwelt:
Short description
The different levels of energy accounting and their respective significance. Calculation methods for the energy intensity of products, taking into account a holistic balancing of the product life cycles. Mechanisms and potentials of rational energy energy use using the example of the building and housing sector.
Contents
The course Man-House-Environment deals with the holistic consideration of energy demand elements during the construction and use up to the demolition of buildings (including the production of building materials). The mechanisms for energy balancing are fundamentally elaborated and their application is deepened in such a way that they are transferable to other life cycle considerations (products, manufacturing components, etc.).

5	**Learning outcomes and competences:** **Expertise:** • The complexity of energy supply, which is usually taken for granted, should be communicated. A central point here is the overall energy balancing approach, which often is neglected. • The interaction of ecological, economic, and sociological factors for the use of the environment as a living space is to be worked out. **Cross-disciplinary competencies:** • In addition to the subject-specific competencies, the course also enables students for general project-related work in their later professional career – by the intensive cooperation during the exercise phase. An important aspect is the mixture of skills that the students from the different disciplines "bring along" through their education.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Prof. Dr.-Ing. Stefan Krauter

Assessment table (item 6):

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination	120-180 min or 30-45 min	100%

13	**Other Notes:** *Remarks of course Mensch-Haus-Umwelt:* **Course Homepage** `http://www.nek.upb.de/lehre/projektarbeiten/mensch-haus-umwelt` **Implementation** In the course, which is offered in the form of a frontal lecture, the students are familiarized with the fundamentals and the calculation methods. In the context of the exercises, the knowledge is deepened and extended through their own examination of the topics. **Teaching Material, Literature** A comprehensive script for the course is provided in which further literature sources are mentioned.

Modellierung von Energiesystemen

Modelling of Energy Systems

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.22019	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.22019 Modelling of Energy Systems	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Modellierung von Energiesystemen:
None

4 **Contents:**

Contents of the course Modellierung von Energiesystemen:
Building on a holistic understanding of energy systems, the course covers the basics of modelling them. For this purpose, starting with simple modelling of stand-alone energy technology components, more extensive energy systems are dealt with step by step. The importance of input data and parameters as well as the effects of different spatial and temporal resolutions are discussed. In addition, various techniques for verification and validation, optimising simulations, for sensitivity analysis and for risk assessment in the context of regenerative energy systems are taught. The lectures are accompanied by practical exercises in which the students gradually deepen the learning content by building and simulating their own models.

5 **Learning outcomes and competences:**

By participating in the course, students are enabled to comprehensively evaluate simulation models and studies as well as to independently model extensive energy systems. Basic techniques of modelling, optimisation and evaluation are learned and can be applied.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Prof. Dr. Henning Meschede
13	**Other Notes:** none

Assessment details (item 6):

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

<table>
<tr><td colspan="5">Solar Electric Energy Systems</td></tr>
<tr><td colspan="5">Solar Electric Energy Systems</td></tr>
<tr><td colspan="2">Module number:
M.048.22013</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
summer term</td></tr>
<tr><td colspan="2">Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.22013
Solar Electric Energy Systems</td><td>2L
2Ex,
SS</td><td>60</td><td>120</td><td>C</td><td>40/40</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
None</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
None
<i>Prerequisites of course Solarelektrische Energiesysteme:</i>
None</td></tr>
</table>

4	**Contents:** *Contents of the course Solarelektrische Energiesysteme:* **Short Description** Conversion of solar energy into electricity for power supply: Basics, properties of devices and materials, performance issues, energy yield, durability, standards, testing, systems, modeling, simulation. **Contents** 1. Potentials, Irradiance, Shadowing 2. Concentration, Solar thermal systems 3. Principle of photovoltaic conversion, making of solar cells, characteristics of photovoltaic conversion devices 4. Manufacturing of solar modules, characteristics, performance 5. PV systems: wiring, inverters, grid-connected system configurations 6. PV systems: Mounting, BoS, Off- vs. On-grid grid Systems, Costs 7. Market development of PV: off-grid markets, markets triggered by feed-in tariffs (FiT), self-sustainable markets, cost and price development 8. Simulation of PV Systems and Microgrids via the HOMER software 9. Performance: optical, thermal and electrical modeling, simulation, measurement 10. Durability of PV modules and systems: Standards, tests, degradation effects 11. Energy Storage 12. Set-up methods for large scale PV power plants 13. PV for general electricity supply: Predictability, combination with other energy sources, Modification, Load Management 14. Excursion to a solar research unit or a solar project
5	**Learning outcomes and competences:** **Domain competence:** After completing the course the students should be Students in a position to: • be familiarized with the basics of solar electric power engineering. • understand the specific characteristics of a power supply via solar-thermal and photovoltaic energy conversion. understand, analyze and evaluate solar electric power plants and to be enabled to plan a layout of a PV power plant **Key qualifications:** The students • are enabled to apply the knowledge and skills across disciplines • are enabled to use method-oriented approaches for the implementation of sustainable energy supply • are enabled to educate themselves in the future.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Prof. Dr.-Ing. Stefan Krauter
13	**Other Notes:** *Remarks of course Solarelektrische Energiesysteme:* **Course Homepage** `http://www.nek.upb.de/lehre` **Implementation** Lecture combined with practical examples & simulations; Excursion to see applications in practice **Teaching Material, Literature** Martin A. Green: Solar Cells Solar Cells: Operating Principles, Technology, and System Applications, UNSW, Sydney, Publisher: Prentice Hall, 1981. Stuart R. Wenham, Martin A. Green, Muriel Watt, Richard Corkish, Alistair Sproul: Applied Photovoltaics, UNSW, Sydney, softcover version: Earthscan, 2012. Stefan Krauter: Solar Electric Power Generation. 1st Ed. Springer: Berlin, Heidelberg, New York, 2006. Stefan Krauter: Solar Electric Power Generation. 2nd Ed. Springer: Berlin, Heidelberg, New York, 2019 (under preparation, preprint available). Stefan Krauter, S.: Simple and effective methods to match photovoltaic power generation to the grid load profile for a PV based energy system. In: Solar Energy 159 (2018) S. 768–776. Stephen W. Fardo, Dale R. Patrick: Electrical Power Systems Technology. The Fairmont Press, Inc., 2009.

Assessment table for item 6:

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

Umweltmesstechnik			
Environmental monitoring and measuring technologies			
Module number: M.048.22010	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.22010 Environmental Monitoring and Measuring Technologies	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Umweltmesstechnik:
None

4 **Contents:**

Contents of the course Umweltmesstechnik:
Short Description:
The ever more intensive use of natural resources is leading to increasing environmental pollution. This course deals with the problems of certain selected impact mechanisms in relation to the impact sites or habitats. The relevant quantities will be characterised and the measurement principles and methods suitable for determining them will be described. In particular, the explanations concentrate on the metrological determination of contamination and monitoring of air, water and soil.
Contents:
The lecture Environmental Monitoring and Measuring Technologies is structured as follows

- Legal framework of environmental protection
- Significance and tasks of environmental monitoring and measuring technology
- Explanation of the mechanisms of action in the increasingly intensive use of natural resources as well as the increasing hazard potential through the use of technologies
- Chemosensor technology and sample preparation
- Measurement principles and methods of environmental measurement technology
- Optodes and optical measurement and analysis technology
- Sensors for liquid analysis
- Sensors for gas analysis

5	**Learning outcomes and competences:** **Domain competence:** After attending the course, students are able to • analyse and understand the mechanisms of action in increasing environmental problems, • to select suitable measurement principles or measurement techniques for selected measurement tasks, considering the concrete measurement conditions, • characterise and interpret measurement results. **Key qualifications:** The Students • can apply the acquired knowledge and skills in an interdisciplinary manner and with complex issues, • are able to develop targeted solutions based on systematic problem analysis, • are capable of familiarising themselves with relevant fields of work due to the method-oriented knowledge transfer.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination	120-180 min or 30-45 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4, UF Technik Lehramt GyGe Master v5, UF Technik Lehramt HRSGe Master v5
12	**Module coordinator:** Prof. Dr. Bernd Henning

13	**Other Notes:** *Remarks of course Umweltmesstechnik:* **Module Homepage** `http://emt.upb.de` **Methodical implementation** • Lectures with slide presentation of extensive correlations • Practical work in groups with measurement technology in the laboratory **Learning materials, references** Provision of a script; references to textbooks from the textbook collection will be announced.

4.2 EE Catalogue Cognitive Systems

Advanced Topics in Robotics

Advanced Topics in Robotics

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92006	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92006 Advanced Topics in Robotics	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced Topics in Robotics:
None

4 **Contents:**

Contents of the course Advanced Topics in Robotics:
Short Description
The course Advanced Topics in Robotics is based on the course Robotics. The students are introduced to current research topics in the field of autonomous and teleoperated mobile robots to solve interdisciplinary issues. The challenges encountered in developing intelligent mobile systems are analyzed and current solutions presented.
Contents

- Architectures of robot systems
- Middleware for hardware abstraction
- Device drivers and libraries
- Visualization
- Local navigation processes (collision avoidance)
- Global navigation processes (pathfinding)
- Navigation and self-localization methods (SLAM)
- Fundamentals of task planning

5 **Learning outcomes and competences:**

Domain competence:
The students

- are able to name and analyze the basic robot architectures for mobile robots,
- have a good command of the methods for the navigation and control of mobile robots and
- are able to implement, test and apply them.

Key qualifications:
The students have a good command of programming in the C language

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Bärbel Mertsching

13 **Other Notes:**

Remarks of course Advanced Topics in Robotics:

ATTENTION - IMPORTANT NOTICE
The course doesn't take place in winter term 2024/25. Please see the notice boards of the group.

Course Homepage
`http://getwww.uni-paderborn.de/teaching/atir`
Implementation

- The theoretical and methodical fundamentals will be introduced during the lecture.
- The methods presented will be practiced during the subsequent exercise / lab part.
- Finally, the participants will implement, test, and apply simple algorithms.
- The necessary programming skills will be taught during the practical, this is explicitly not considered a programming course.

Teaching Material, Literature
Allocation of lecture notes; information on textbooks stocked in the textbook collection will be announced later.

- Mertsching, Bärbel: Robotics (lecture notes)
- McKerrow, Phillip J.: Introduction to Robotics. Addison-Wesley, 1991
- Siegwart, Roland; Nourbakhsh, Illah R. and Scaramuzza, David: Introduction to Autonomous Mobile Robots. The MIT Press, 2011, ISBN-13: 978-0262015356

Digital Image Processing I			
Digital Image Processing I			
Module number: M.048.92008	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92008 Digital Image Processing I	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Digital Image Processing I:
None. Basic programming knowledge is an advantage.

4 **Contents:**

Contents of the course Digital Image Processing I:
Short Description
This course provides a fundamental introduction to digital image processing. Upon successful completion, students will be able to thoroughly describe the basic concepts of image generation and representation. Additionally, they will acquire the skills to apply methods for enhancing and segmenting grayscale and color images in both the spatial and frequency domains, as well as techniques for image compression. Students will be capable of independently selecting, implementing, testing, and applying these techniques to complex image processing tasks. A typical application area is automation technology.
Contents

1. Introduction (Graphics File Formats, Application Examples, Human Vision) 2.Image Formation and Image Models (Camera Models, Image Formation, Image Sampling and Quantization)
2. Image Enhancement in the Spatial Domain (Gray-Level Transformation Functions, Histogram Processing, Spatial Filtering)
3. Image Enhancement in the Frequency Domain (2D Fourier Transform, Smoothing and Sharpening Filters, Implementation Details)
4. Color Image Processing (Color Spaces, Color and Pseudo-Color Image Processing, Spatial Filtering)
5. Image Compression and Reduction (Types of Redundancy, Compression Models, Lossless and Lossy Compression)

5 **Learning outcomes and competences:**

Domain competence
The students

- are able to describe the basics of image generation and image digitization and
- are able to select, implement, test and apply methods for the enhancement of images in the spatial and frequency domain, image segmentation and data reduction independently for complex image processing tasks.

Key qualifications
The students have a good command of programming in Python.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

none

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Markus Hennig
13	**Other Notes:** *Remarks of course Digital Image Processing I:* **Target group** Master's students in electrical engineering and related fields. **Course Homepage** `https://ei.uni-paderborn.de/get/teaching/dip-i` **Literature** • Gonzalez, R., & Woods, R. (2017). Digital Image Processing (4th Global Ed.). Pearson. Print ISBN: 978-1-292-22304-9, E-ISBN: 978-1-292-22307-0. • Mertsching, B. (2024). Digital Image Processing I (Lecture Notes). • Jähne, B. (2024). Digitale Bildverarbeitung (8th Edition, German Language). Springer. Print ISBN: 978-3-662-59509-1, E-ISBN: 978-3-662-59510-7. **Comment** The material presented in the lecture is implemented in the exercises using Python. The first exercise provides an introduction to this, so that it is possible to get started with limited programming knowledge. Regular and active participation in lectures and exercises is expected.

Digital Image Processing II			
Digital Image Processing II			
Module number: M.048.92010	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92010 Digital Image Processing II	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Digital Image Processing II:
Recommended:
Basic knowledge of image processing, (e. g. from the course Digital Image Processing I (L.048.23002 / L.048.92008)

4 **Contents:**

Contents of the course Digital Image Processing II:
Short Description
The course “Digital Image Processing II” is a module in the catalog “Cognitive Systems” for advanced students of the Electrical Engineering Master’s program and related degree programs. It follows the fundamental course “Digital Image Processing I” and covers methods for high-level image processing.
Contents
The following topics will be discussed during the semester:

- Image segmentation (line and edge detection, segmentation by region, superpixels)
- Feature extraction (feature descriptors, principal components, Scale-Invariant-Feature-Transform (SIFT))
- Stereo image analysis (depth perception, stereo geometry, correspondence problem)
- Motion (motion detection, optical flow, motion models, motion segmentation)
- Object recognition and image pattern classification (patterns, classifiers, neural networks and deep learning, convolutional neural networks (CNN))

After learning about the methods in the lecture, the students will implement them in Jupyter Notebooks.

5 **Learning outcomes and competences:**

Domain competence:
The students

- can apply methods for image segmentation, representation and description of features, stereo and motion image analyis, objection recognition and machine learning,
- are able to transfer the acquired knowledge of image processing to the processing of other multi-dimensional signals,
- are able to describe the state-of-the-art of the presented topics, and
- are able to implement the presented methods.

Key qualifications:
The students are able to identify and evaluate the function and the behavior of complex technical processes and their integration into the social environment while also considering ethical aspects.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Bärbel Mertsching

13 **Other Notes:**

Remarks of course Digital Image Processing II:
Course Homepage
[http://getwww.uni-paderborn.de/teaching/dip-II]
Course Documents
see PANDA ([https://panda.uni-paderborn.de])
References (excerpt)

- Mertsching, Bärbel: Digital Image Processing (lecture notes)
- Forsyth, David and Ponce, Jean: Computer Vision - A Modern Approach. Prentice-Hall, 2nd ed., 2011. ASIN: B006V372KG
- Gonzalez, Rafael C. and Woods, Richard E.: Digital Image Processing. Pearson Education Limited, 4th ed., 2018. ISBN-13: 978-1-292-22304-9
- Jähne, Bernd: Digitale Bildverarbeitung. Springer, 7. Aufl., 2012. ISBN-13: 978-3642049514

Reinforcement Learning			
Reinforcement Learning			
Module number: M.048.92045	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92045 Reinforcement Learning	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Reinforcement Learning:
Recommended: It is recommended to have a sound basic knowledge in the field of system and control theory. Ideally, the students have knowledge in the field of un-/supervised machine learning and numerical optimization. In addition, at least some experience with Python will be advantageous for the exercise and tutorial tasks.

4 **Contents:**

Contents of the course Reinforcement Learning:
The course covers the basics of reinforcement learning (RL) in an engineering context. RL stands for a series of methods of machine learning in which an agent independently learns a strategy (policy) to maximize the rewards received during interaction with an (unknown) system. This can be, for example, a control loop in which an adaptive controller tries to determine an optimal control law from previous observations of the control and measurement variables, which maximizes certain benchmark criteria with regard to controller performance. Well-known fields of application include the operation of autonomous vehicles and industrial robots or the identification of optimal strategies in the context of leisure games.
The course has an application-oriented focus in the engineering sciences but is also designed for students of natural sciences (e.g. computer science, mathematics). In addition to teaching the methodological fundamentals within the lecture, great importance is attached to practical implementation and programming tasks during the exercise and tutorial hours.
The course will cover the following content:

- Conceptual basics and historical overview
- Markov decision processes
- Dynamic programming
- Monte Carlo learning
- Temporal difference learning
- Bootstrapping
- Function approximation and deep learning
- On- and Off-policy strategies
- Policy gradient methods
- Trust region methods

5 **Learning outcomes and competences:**

Domain-specific competences
After attending the course, the students are able to

- differentiate, apply and analyze RL methods,
- name and explain differences as well as advantages and disadvantages of RL compared to neighboring approaches (e.g. model-predictive control),
- educate themselves independently in this branch of science on the basis of the methods learned for the analysis and synthesis of RL techniques.

Interdisciplinary competences
The students

- can apply or transfer the acquired knowledge to interdisciplinary problems,
- have gained practical experience in programming which they can use across domains and
- are able to critically evaluate methods and results.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Dr Jarren Lange
13	**Other Notes:** *Remarks of course Reinforcement Learning:* **Course homepage** `https://en.ei.uni-paderborn.de/rat` https://github.com (open-source course material) **Implementation** • Slide-based lecture, which also serves as lecture notes. • Presence exercises with tutorial sheets (with many programming tasks) **Main literature** • Richard S. Sutton, Andrew G. Barto, „Reinforcement Learning“, 2. Ed., MIT Press, 2018 • David Silver, „Reinforcement Learning“ (Skriptum), University College London, 2015

Robotics

Robotics

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92012	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92012 Robotics	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Robotics:
None

4 **Contents:**

Contents of the course Robotics:
Short Description
The course “Robotics” is a fundamental module in the catalog “Cognitive Systems” of the Electrical Engineering Master’s program and related degree programs. It is the first of two courses that cover the relevant concepts and techniques in the field of robot manipulators and mobile robots. This course concentrates on modeling and controlling robot arms, while its successor in the winter semester (Advanced Topics in Robotics (L.048.23020 / L.048.92006) focuses on mobile robots. The challenges for the development of autonomous intelligent systems will be analyzed and the current solutions will be presented.
Contents

- Sensors, effectors, actuators
- Homogenous coordinates, general transformations, Denavit-Hartenberg parameters
- Kinematics and dynamics of robot arms and mobile robots

After the presentation of methods in the lecture, the students will use Matlab and Octave to implement them.

5 **Learning outcomes and competences:**

Domain competence:
The students

- know how to transfer basic methods from control and system theory to robotics and
- are able to apply adequate methods to model as well as plan and control the movements of robot arms.

Key qualifications:
The students are able to identify and evaluate the function and behavior of robots and their integration into the social and economic environment while also considering ethical aspects.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Bärbel Mertsching

13	**Other Notes:** *Remarks of course Robotics:* **Course Homepage** [http://getwww.uni-paderborn.de/teaching/robotik] **Course Documents** see PANDA ([https://panda.uni-paderborn.de]) **References (excerpt)** • Mertsching, Bärbel: Robotics (lecture notes) • McKerrow, Phillip J.: Introduction to Robotics. Addison-Wesley, 1991 • Lynch, Kevin M. and Park, Frank C.: Modern Robotics: Mechanics, Planning, and Control. Cambridge University Press, 2017. ISBN-13 : 978-1107156302

Statistical and Machine Learning

Statistical and Machine Learning

Module number: M.048.23012	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.23012 Statistical and Machine Learning	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Statistical and Machine Learning:
Recommended: Elementary knowledge in probability theory, as is taught in the course Statistical Signal Processing. Basic programming skills are desirable.

4 **Contents:**

Contents of the course Statistical and Machine Learning:
Short Description
The course on Statistical and Machine Learning presents an introduction into the components and algorithms prevalent in statistical and machine learning. Modern techniques will be presented for gleaning information from data. Both supervised and unsupervised learning algorithms will be discussed. The presented techniques can be applied to a variety of classification and regression problems, both for one-dimensional input data (e.g., speech), two-dimensional (e.g., image) or symbolic input data (e.g., documents).
Contents
Introduction to classification problems, Bayesian and other decision rules Optimization: gradient descent, algorithmic differentiation, optimization with constraints *Linear classifiers, Support Vector Machines* Deep neural networks (deep learning) *Dimensionality reduction (PCA, LDA)* Unsupervised learning (mixture densities, clustering techniques)

5 **Learning outcomes and competences:**

Domain competence:
After completion of the module students will be able to

- Find an appropriate approach to solving a given classification or regression problem
- Apply supervised or unsupervised learning techniques to data of various kinds and critically assess the outcome of the learning algorithms
- Can appreciate the power and limitations of machine learning algorithms
- Work with software for solving machine learning problems and write own software components, apply them to given data sets and optimize parameter settings
- Find, for a given training set size, an appropriate choice of classifier complexity und feature vector dimensionality

Key qualifications:
The students

- Have gathered sufficient proficiency in Python, which is valuable well beyond this course
- Can assess the importance of the principle of parsimony and are able to transfer it to other
- Are able to analyse a given classification or regression problem, synthesize a solution, and evaluate the performance on test data
- Are able to apply the knowledge and skills learnt in this course to a wide range of disciplines
- Can work cooperatively in a team and subdivide an overall task into manageable subtasks and work packages
- Acquired a general understanding of the power and limitations of machine learning algorithms

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Reinhold Häb-Umbach
13	**Other Notes:** *Remarks of course Statistical and Machine Learning:* **Course Homepage** `https://ei.uni-paderborn.de/en/statistical-and-machine-learning` **Implementation** *Lectures predominantly using the blackboard or overhead projector, occasional presentations of (powerpoint) slides ,* Exercise classes with exercise sheets and demonstrations on computer *Implementation of learning and classification algorithms on a computer by the students themselves; use of algorithms on real-world data or data generated on the computer, evaluation of the simulation results **Teaching Material, Literature** Course script and summary slides are provided to the students. Exercises and solutions to exercises, as well as sample implementations of algorithms are provided to the students *R.O. Duda, P.E. Hart, D.G.~ Stork, Pattern Classification, Wiley, 2001* I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016 *S. Theodoridis: Machine Learning, Academic Press, 2015* K. Fukunaga, Introduction to Statistical Pattern Recognition, Academic Press, 1990

<table>
<tr><th colspan="5">Technische kognitive Systeme - Ausgewählte Kapitel</th></tr>
<tr><td colspan="5">Cognitive Systems Engineering - Special Topics</td></tr>
<tr><td colspan="2">Module number:
M.048.23019</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
summer- / winter term</td></tr>
<tr><td colspan="2">Language:
de / en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
<tr><td>1</td><td colspan="4">Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.23019
Cognitive Systems Engineering - Special Topics</td><td>2L
2Ex,
WS</td><td>60</td><td>120</td><td>C</td><td>40/40</td></tr>
</table></td></tr>
<tr><td>2</td><td colspan="4">Options within the module:
two out of three topics, see point 4</td></tr>
<tr><td>3</td><td colspan="4">Admission requirements:
None
<i>Prerequisites of course Technische kognitive Systeme - Ausgewählte Kapitel:</i>
Recommended: Interest in the subject-matter and interdisciplinary work.</td></tr>
</table>

4	**Contents:** This module is offered in three parts. Students have to choose **two out of three**. Each part lasts two hours per week. *Contents of the course Technische kognitive Systeme - Ausgewählte Kapitel:* **Part A** At any given time, the sensory receptors of living beings are exposed to a very large amount of information, of which only a small proportion can be consciously processed. Visual attention is understood as the pooling of available cognitive resources for optimal processing of visual stimuli. The seminar introduces the modeling and experimental investigation of visual attention and the transfer to intelligent technical systems. It will be shown how research can be conducted jointly across disciplinary boundaries. The current focus is on the topic of saliency. The course always takes place in the winter semester. **Part B** While “sensation” describes the signals from the physical world that reach our sensory receptors, “perception” refers to the processes by which our brain selects, organizes, and interprets the signals. This seminar provides students in technical courses with an overview of the fundamentals of biological sensory systems and perception. In addition to the exciting and (sometimes non-intuitive) background of these topics, there will be a critical discussion of the transferability of biological concepts and mechanisms to technical systems. This seminar is always in the summer semester. **Part C** In this seminar, current interim reports and results from ongoing bachelor’s and master’s theses, research projects, and third-party funded projects from the GETLab - Technical Cognitive Systems department will be presented. Furthermore, there will be presentations by guests of the research group. The seminar is offered in the summer and winter semester.
5	**Learning outcomes and competences:** **Domain competence:** The students • are able to name basic research topics related to the design and the implementation of technical cognitive systems, • can apply and evaluate technical cognitive systems, and • are able to understand, design, implement and evaluate basic psychophysical experiments. **Key qualifications:** The students • are able to research and evaluate technical literature, • have developed an understanding of the discipline-related research approaches (computer science, electrical engineering, psychology) and • are able to carefully consider the potential use of bio-inspired mechanisms in technical systems.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Bärbel Mertsching
13	**Other Notes:** **Module Homepage** [http://getwww.uni-paderborn.de/teaching/cse] **Teaching Material, Literature** Literature references will be given at the first dates of the seminar. *Remarks of course Technische kognitive Systeme - Ausgewählte Kapitel:* --- **ATTENTION - IMPORTANT NOTICE** The course doesn't take place in winter term 2024/25. Please see the notice boards of the group. ---

Topics in Pattern Recognition and Machine Learning			
Topics in Pattern Recognition and Machine Learning			
Module number: M.048.92030	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92030 Topics in Pattern Recognition and Machine Learning	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Topics in Pattern Recognition and Machine Learning:
Recommended: Elementary knowledge in Probability Theory, as is taught in the module Statistical Signal Processing. Desirable, but not mandatory: knowledge in the field of statistical and machine learning; basic programming skills

4 **Contents:**

Contents of the course Topics in Pattern Recognition and Machine Learning:
Short Description
The course on Topics in Pattern Recognition and Machine Learning first briefly summarizes the main concepts of statistical pattern recognition and machine learning. Next selected topics will be presented in detail. The choice of topics depends on current research activities and thus may change over time. Examples of such topics to be studied in detail include

- Deep Learning
- Model estimation in the presence of hidden variables, in order to reveal suspected latent structure buried in the data
- Bias-Variance dilemma and the tradeoff between degree of detail and generalizability of models
- Grafical models
- Sequential data and hidden Markov models
- Decision trees, model combination
- Specific classification tasks, such as automatic speech recognition While the first part of the course will follow a regular lecture format, the second part will include active student participation. Students will be asked to read, analyze and present recently published papers from the pattern recognition and machine learning literature. This will often also include the implementation of proposed algorithms in Matlab.

Contents

- Fundamentals of statistical pattern recognition: Bayes rule, learning of class-conditional densities, linear models for classification and regression
- Deep neural networks: MLP, CNN, RNN and others
- EM Algorithm and extensions thereof
- Models with discrete or continuous latent variables; GMM, NMF
- Bias-Variance dilemma and model selection
- Graphical models
- Hidden Markov models and their application in speech recognition
- Decision trees, model combination
- Recent publications in pattern recognition and machine learning

5 **Learning outcomes and competences:**

Domain competence:
After completion of the course students will be able to * Choose an appropriate classifier for a given classification problem and be able to learn the parameters of the classifier from training data

- Choose an appropriate regression method for function approximation and learn its parameters from training data
- Search for latent variables and structure in given data
- Make an informative choice for the model order to find a good compromise between degree of detail and generalizabliliy
- Comprehend and analyze recent publications from the field of pattern recognition and machine learning

Key qualifications:
The students

- Have gathered an understanding of the importance of the chosen model order on the outcome of classification and regression tasks
- Are aware of the impact of a priori assumptions on the result of latent variable and structure discovery in data
- Are able to autonomously gain expertise in a certain field of pattern recognition by conducting a literature survey
- Can gauge the importance of a given publication for the state of the art in a field
- Are able to apply the knowledge and skills learnt in this course to a wide range of disciplines

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Häb-Umbach
13	**Other Notes:** *Remarks of course Topics in Pattern Recognition and Machine Learning:* **Course Homepage** `https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/topics-in-pattern-recognition-and-maschine-learning` **Implementation** • Lectures predominantly using the blackboard or overhead projector, occasional presentations of (powerpoint) slides , • Exercise classes with exercise sheets and demonstrations on computer • Instructions how to read and analyze scientific publications in this field Autonomous analysis of publications and presentation of results and gained insight **Teaching Material, Literature** • R.O. Duda, P.E. Hart, D.G.~ Stork, Pattern Classification, Wiley, 2001 • I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, MIT Press, 2016 • C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006

4.3 EE Catalogue Communications

Ausgewählte Kapitel der theoretischen Elektrotechnik			
Selected Topics in Theoretical Electrical Engineering			
Module number: M.048.24023	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer- / winter term
Language: de	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.24023 Selected Topics of Theoretical Electrical Engineering	2L 2Ex, WS+SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Ausgewählte Kapitel der theoretischen Elektrotechnik:
Recommended: Basic knowledge from the compulsory module Theoretical Electrical Engineering

4

Contents:

Contents of the course Ausgewählte Kapitel der theoretischen Elektrotechnik:
Short Description
The course Selected Topics of Theoretical Electrical Engineering extends and deepens the knowledge of electromagnetic wave propagation in free space and on waveguides acquired in the compulsory course Theoretical Electrical Engineering by selected topics. Based on the theory of longitudinally homogeneous waveguides, the system description by means of scattering parameters as well as the mode-matching method are practically motivated and treated in terms of wave theory. Another thematic focus is the Green's method for the mathematical solution of boundary value problems, which is derived in detail and applied to electromagnetic field problems.
Contents
The lecture Selected Topics of Theoretical Electrical Engineering is organized as follows:

- Theory of eigenwaves and its application in scattering parameter theory.
- Ez-Hz field approach for longitudinal homogeneous waveguide structures
- System description by means of scattering matrices
- Basics of the mode-matching method
- Green's method in electromagnetic field theory
- Green's functions and their determination
- The aperture field method in antenna theory
- Solution of physical field problems by means of Green's functions

5

Learning outcomes and competences:

Domain competence:
After attending the course, the student will be able to

- mathematically model simple physical field problems
- transfer, apply, validate numerical methods on physical problems
- to physically interpret and visualise the obtained results

Key qualifications:
The students

- learn to transfer the acquired skills also to other disciplines
- extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises
- learn strategies to acquire knowledge from literature and internet

6

Assessments:

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7

Study Achievement:

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Dr.-Ing. Denis Sievers
13	**Other Notes:** *Remarks of course Ausgewählte Kapitel der theoretischen Elektrotechnik:* **Course Homepage** `http://www.tet.upb.de` **Implementation** The theoretical concepts are presented in the form of a lecture, which also includes a large proportion of field visualizations. In the exercises, the theory is deepened by means of simple questions and calculation examples, which are solved independently during the presence exercises. **Teaching Material, Literature** Lecture slides and blackboard notes, additional recommended reading will be announced in lecture.

Digitale Sprachsignalverarbeitung			
Digital Speech Signal Processing			
Module number: M.048.24001	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.24001 Digital Speech Signal Processing	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Digitale Sprachsignalverarbeitung:
Recommended: Prior knowledge from the module Higher Mathematics.

4 **Contents:**

Contents of the course Digitale Sprachsignalverarbeitung:

Short Description

The course introduces the basic techniques and theories of digital speech signal processing. A focal point of the first part of the lecture is the topic “Listening and Speaking”, which is concerned with psychological effects of human sound perception and speech production. Subsequently, time discrete signals and systems, as well as computer based data processing are discussed. Further topics are non-parametric short-time analysis of speech signals, speech coding and IP-phones.

Contents

- Listen and talk
- Generating voice: human vocal tract, source filter model, vocoder
- Acoustic waves
- Listen: human ear, psycho acoustics and physiology of listening, loudness, acoustic occlusion, frequency groups
- Time-discrete signals and systems
- Basics: Elementary signals, LTI systems
- Transformations: Fourier transformation of time-discrete signals, DFT, FFT
- Time-discrete filtering in frequency domain: Overlap-Add, overlap-Save
- Statistical speech signal analysis
- Basics in theory of probabilities
- Short-run analysis of speech signals: Spectrogram, cepstrum
- Estimation of speech signals
- Optimal filters
- LPC analysis
- Spectral filtering for noise suppression: spectral subtraction, Wiener filter
- Adaptive Filters: LMS adaptation algorithm, echo compensation
- Speech coding
- Time domain coding: signal shape coding, parametric coding, hybride coding tech-niques
- Frequency domain coding
- Amplitude quantization: uniform quantization, quantization with companders (ulaw, alaw)

5 **Learning outcomes and competences:**

Domain competence:

After attending the course, the students will be able to

- analyze digital signals, e.g., audio signals, in the time or frequency domain,
- represent audio signals efficiently and
- implement widely-used algorithms for speech analysis and speech processing in the frequency or time domain.

Key qualifications:

The students

- are able to explain effects in real signals based on the theoretical knowledge,
- are able to investigate theoretical approaches by a systematic analysis and
- are, due to the precise treatment of the contents, in a position to continue their learning themselves

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Informatik v4, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Dr.-Ing. Jörg Schmalenströer
13	**Other Notes:** *Remarks of course Digitale Sprachsignalverarbeitung:* **Course Homepage** `https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/digital-speech-signal-processing` **Implementation** • Lectures using the blackboard and presentations, • Alternating theoretical and practical exercise classes with exercise sheets and computer and • Demonstration of real technical systems in the lecture hall. **Teaching Material, Literature** Allocation of a script; information on textbooks ; matlab scripts

Elektromagnetische Feldsimulation			
Simulation of Electromagnetic Fields			
Module number: M.048.24006	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer- / winter term
Language: de	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.24006 Simulation of Electromagnetic Fields	2L 2Ex, WS+SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Elektromagnetische Feldsimulation:
Recommended: In-depth knowledge of electromagnetic field theory taught in the modules “Field Theory”, “Electromagnetic Waves” and “Theoretical Electrical Engineering”.

4 **Contents:**

Contents of the course Elektromagnetische Feldsimulation:
Short description
The course Electromagnetic Field Simulation offers an introduction to modern simulation methods for electromagnetic field problems. The focus is on the method Finite Integration (FIT), a modern, very efficient and successful approach from the class of grid-based methods. Field problems of statics, quasistatics and fast-varying fields (electromagnetic waves) with almost arbitrary material distribution can be treated. The modeling with FIT leads to algebraic matrix equations, whose solution is also discussed in an introductory way. In addition, some related methods such as finite differences and finite elements will be discussed. One of the aims of the course is to get to know and to be able to assess the possibilities and limitations of the discussed methods in practical use. In addition, the foundation is laid for further development of the algorithms in the context of scientific projects.
Contents
as follows

- Introduction
- Motivation
- Classification of solution methods
- Numerical approaches
- Fundamentals of the finite integration method
- Lattice Maxwell equations
- Properties of discretization matrices
- Boundary conditions
- Solution of electromagnetic field problems
- Static fields
- Time-varying fields
- Time-harmonic fields (frequency domain)
- Transient fields (time domain)

5 **Learning outcomes and competences:**

Specialized competence:
After attending the course, students will be able to,

- formulate complex electromagnetic field problems mathematically (modeling, analyzing)
- to apply the Fnite integration method to physical problems (apply, synthesize, evaluate)
- visualize numerically obtained results and interpret them physically (Evaluate).

Cross-disciplinary competencies:
The students

- learn to apply the acquired knowledge and skills across disciplines,
- expand their cooperation and teamwork skills as well as presentation skills when working on exercises
- learn strategies for acquiring knowledge by studying literature and using the Internet,
- acquire a subject-related foreign language competence

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12 **Module coordinator:**

Dr.-Ing. Denis Sievers

13	**Other Notes:** *Remarks of course Elektromagnetische Feldsimulation:* **Course Homepage** `http://www.tet.upb.de` **Implementation** The theoretical concepts are presented in the form of a lecture, and in the associated practical programming exercise, small Matlab programs are created for simple problems in simulation technology. **Teaching Material, Literature** Lecture slides and blackboard notes

Feldberechnung mit der Randelementmethode			
Field Computation Using Boundary Element Method			
Module number: M.048.24013	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer- / winter term
Language: de	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.24013 Field Computation Using Boundary Element Method	2L 2Ex, WS+SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Feldberechnung mit der Randelementmethode:
Recommended: In-depth knowledge of electromagnetic field theory taught in the modules “Field Theory”, “Electromagnetic Waves” and “Theoretical Electrical Engineering”.

4 **Contents:**

Contents of the course Feldberechnung mit der Randelementmethode:
Short description
The course Field Calculation with the Boundary Element Method focuses on a discretization method which is preferably used in antenna technology for the solution of radiation problems as well as in radar technology for the analysis of scattering objects. From the numerically determined results, important parameters such as the directivity of antennas or the backscatter cross section of radar targets can be derived. The aim of the lecture is to impart the theoretical basic knowledge about the boundary element method under consideration of application-related aspects, with the main focus on the use in engineering practice.
**Content
The lecture Field Calculation with the Boundary Element Method is structured as follows: 1. introduction (motivation, mathematical basics) 2. integral equation method (representation formulas for electromagnetic fields, surface integral equations) 3. mathematical modeling (formulation of antenna, scattering and eigenvalue problems, excitation modes, calculation of backscattering cross sections and antenna parameters) 4. discretization by means of the method of moments (principle of projection methods, basis functions) 5. calculation of matrix contributions (numerical integration, treatment of singular integrals) 6. aspects of solving the discrete model problem (solution strategies, matrix compression methods)

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Specialized competence:
After attending the course, students will be able to,
formulate complex electromagnetic field problems mathematically (modeling, analyzing)
transfer, apply and test the boundary element method to physical problems (apply, synthesize, evaluate)
visualize numerically obtained results and interpret them physically (Evaluate).
Cross-disciplinary competencies:
The students
learn to apply the acquired knowledge and skills across disciplines,
expand their cooperation and teamwork skills as well as presentation skills when working on exercises
learn strategies for acquiring knowledge by studying literature and using the Internet,
acquire a subject-related foreign language competence</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr.-Ing. Denis Sievers</td></tr>
</table>

13	**Other Notes:** *Remarks of course Feldberechnung mit der Randelementmethode:* **Course Homepage** `http://tet.upb.de/` **Implementation** The theoretical concepts will be presented in the form of a lecture accompanied by a practical programming exercise in which the algorithms presented will be implemented on a computer and tested using simple practical examples. **Teaching Material, Literature** Lecture slides and blackboard notes, additional recommended reading will be announced in lecture.

Hochfrequenztechnik			
High Frequency Engineering			
Module number: M.048.24007	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.24007 High-Frequency Engineering	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Hochfrequenztechnik:
None

4 **Contents:**

Contents of the course Hochfrequenztechnik:
Short Description
This lecture gives application-oriented knowledge in high frequency engineering. Furthermore, it gives knowledge in active and passive high-frequency circuits.
Contents
The lecture High-Frequency Engineering (4 SWS, 6 ECTS credit points) extends the content of the lecture Theoretische Elektrotechnik by further application-relevant knowledge. The aim is to qualify the students for development tasks for example in the radio frequency part of a mobile telephone. But considerations of high-frequency engineering are also needed in prevalent digital circuits. The emphases of the lecture are passive devices, high-frequency properties of fundamental transistor circuits, linear and nonlinear amplifiers, noisy multiports, mixers, oscillators, injection-locking and phase-locked loop

<table>
<tr><td>5</td><td>Learning outcomes and competences:
**Professional Competence
After attending the course, the students will be able, in the taught extent, to understand the function of components, circuits and systems of high-frequency engineering, to model and to apply them.
Key qualifications: The students
are able to apply the knowledge and skills to a wide range of disciplines,
are able to make use of a methodical procedure when undertaking systematic analysis and
are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Reinhold Noé</td></tr>
</table>

13 **Other Notes:**

Remarks of course Hochfrequenztechnik:
Course Homepage
`http://ont.upb.de`
Implementation
Lecture and exercise
Teaching Material, Literature
Scripts, exercise sheets and advanced literature (excerpt):

- Thiede, A.: Skriptum Hochfrequenzelektronik/High-Frequency Electronics, Universität Paderborn
- Sze, S. M.: High Speed Semiconductor Devices, John Wiley & Sons, 1990
- Herbst, L. J.: Integrated Circuit Engineering, Oxford University Press, 1996
- Yip, P. C. L.: High-Frequency Circuit Design and Measurement, Chapman & Hall, 1996
- Gonzalez, G.: Microwave Transistor Amplifiers, Prentice Hall, 1997
- Hoffmann, M.: Hochfrequenztechnik, Springer, 1997

Numerische Simulation mit der Discontinuous Galerkin Time Domain Methode

Numerical Simulations with the Discontinuous Galerkin Time Domain Method

Module number:	Workload (h):	Credits:	Regular Cycle:
M.048.24018	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de / en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.24018 Numerical Simulations with the Discontinuous Galerkin Time Domain	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Numerische Simulation mit der Discontinuous Galerkin Time Domain Methode:
Recommended: Detailed knowledge of the Maxwell Equations, their properities and solutions as taught in the course Fields&Waves. Mathematical basis knowledge on differential equations and vector analysis.

4 **Contents:**

Contents of the course Numerische Simulation mit der Discontinuous Galerkin Time Domain Methode:
Short Description
This course provides an introduction tot he sophisticated and powerful Discontinuous Galerkin method in time domain. With this numerical technique it is possible to describe spatiotermporal effects like electromagnetic field propagation and other physical models which can be described by partial differential equations.
Contents

- Introduction, Motivation, History
- Basic elements of the Discontinuous Galerkin Method
- Linear systems * Theory foundation and discrete stability
- Nonlinear problems and properties
- Higher order, global problems
- Application to electromagnetic field simulation

5	**Learning outcomes and competences:** **Domain competence:** After attending the course, the student will be able to • mathematically model complex electromagnetic field problems • transfer, apply, validate the Discontinuous Galerkin method on physical problems • to physically interpret and visualise the obtained results **Key qualifications:** The students • learn to transfer the acquired skills also to other disciplines • extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises • learn strategies to acquire knowledge from literature and internet • acquire a specialised foreign language competence
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Jens Förstner

Assessments (6):

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination	90-150 min or 20-30 min	100%

13	**Other Notes:** *Remarks of course Numerische Simulation mit der Discontinuous Galerkin Time Domain Methode:* **Implementation** The theoretical concepts are presented in form of a lecture. In the corresponding exercises simulation techniques are practised by writing or adapting small programs.

Optical Waveguide Theory			
Optical Waveguide Theory			
Module number: M.048.24019	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.24019 Optical Waveguide Theory	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Waveguide Theory:
Recommended: Bachelor-level knowledge in electrodynamics and mathematics as taught in the course Fields&Waves.

4 **Contents:**

Contents of the course Optical Waveguide Theory:
Short Description
Dielectric optical waveguides constitute key-elements of present-day integrated optical / photonic circuits. This course provides an introduction to their theoretical background, and, as such, a sound basis for further, more specific, modelling, simulation, and design work, as well as for experimental activities in the field.
Contents

- Photonics / integrated optics, dielectric waveguides: introductory examples, motivation.
- Brush up on mathematical tools.
- Maxwell equations, survey of different formulations; classes of simulation tasks.
- Normal modes of dielectric optical waveguides, orthogonality, completeness, scattering matrices, reciprocal circuits.
- Examples for dielectric optical waveguides (multilayer slabs, integrated optical channels, fibers), bent waveguides, whispering gallery resonances.
- Coupled mode theory, conventional codirectional, and hybrid analytical / numerical variant, perturbations of optical waveguides.
- Optional, brief remarks on: boundary conditions, initial value problems (beam propagation method), waveguide discontinuities (BEP/QUEP simulations), photonic crystal waveguides & fibers, plasmonic waveguides.

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the student will be able to

- to mathematically model electromagnetic field problems of systems in integrated optics and photonics
- to identify, apply and verify appropriate analytical methods and approximation techniques
- to physically interpret and visualise the obtained results
- to extend, develop and validate theoretical models for integrated optics and photonics

Key qualifications:
The students

- learn to transfer the acquired skills also to other disciplines
- extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises
- learn strategies to acquire knowledge from literature and internet
- acquire a specialised foreign language competence

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12 **Module coordinator:**

Dr. Manfred Hammer

13	**Other Notes:** *Remarks of course Optical Waveguide Theory:* **CourseHomepage** `http://ei.uni-paderborn.de/tet/` **Implementation** The theoretical concepts will be presented as a lecture. The methods presented will be practiced in exercises classes and by means of homework assignments.

Optimale und Adaptive Filter

Optimal and Adaptive Filters

Module number:	Workload (h):	Credits:	Regular Cycle:
M.048.24010	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de / en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.24010 Optimal and Adaptive Filters	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optimale und Adaptive Filter:
Recommended: Prior knowledge from the modules Higher Mathematics and Digital Signal Processing.

4 **Contents:**

Contents of the course Optimale und Adaptive Filter:
Short Description
The course “Optimal and adaptive filters” gives an introduction to the basic techniques and theories of adaptive filters. Based upon the basics of estimation theory optimal filters are discussed. Subsequently the topics Wiener filter theory, deterministic optimization under constraints and stochastic gradient methods are regarded. Concluding the Least Squares approach for solving filter tasks and the Kalman filter are introduced. The latter is regarded as a brief introduction to state based filters.
Contents

- Classic parameter estimation
- Estimators
- MMSE-Estimation
- Linear estimators
- Orthogonality principle
- Evaluation of estimators
- Wiener filter
- Wiener-Hopf equation
- AR- and MA processes
- Linear prediction
- Iterative optimization methods
- Gradient ascent/descent
- Newton method
- Linear adaptive filters
- LMS algorithm
- Least-Squares method
- Blockwise and recursive adaptiv filters
- Realization aspects
- Statemodel based filters
- Kalman filter
- Applications
- System identification
- Channel estimation and equalization
- Multi-channel speech signal processing
- Noise and interference suppression

5

Learning outcomes and competences:

Domain competence:
After attending the course, the students will be able to

- analyze task on the field of adaptive filters and to formulate requirements mathematically,
- develop filter using cost functions and
- implement selected adaptive filters in the frequency or time domain.

Key qualifications:
The students

- are able to check theoretical results using practical realizations,
- are able to undertake theoretical approaches a systematic analysis using methodical procedures and
- are, due to the precise treatment of the contents, in a position to continue their learning themselves.

6

Assessments:

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7

Study Achievement:

none

8

Prerequisites for participation in examinations:

None

9

Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.

10

Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).

11

Reuse in degree courses or degree course versions :

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12

Module coordinator:

Dr.-Ing. Jörg Schmalenströer

13	**Other Notes:** *Remarks of course Optimale und Adaptive Filter:* **Course Homepage** `https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/optimal-and-adaptive-filter` **Implementation** • Lectures using the blackboard and presentations, • Alternating theoretical and practical exercises classes with exercise sheets and computer and • Demonstration of real technical systems in the lecture hall. **Teaching Material, Literature** Allocation of a script; information on textbooks; matlab scripts

<table>
<tr><th colspan="4">Topics in Signal Processing</th></tr>
<tr><td colspan="4">Topics in Signal Processing</td></tr>
<tr><td>Module number:
M.048.92014</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
winter term</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
</table>

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92014 Topics in Signal Processing	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Topics in Signal Processing:
Recommended: Signal and system theory, at least a basic understanding of probability and linear algebra

4 **Contents:**

Contents of the course Topics in Signal Processing:
Short Description
This course covers a selection of current topics in signal processing. One part of this course will follow a regular lecture format, while the other part will require active student participation.
Contents
This course will first review relevant aspects of linear algebra and probability theory. Then students will learn how to read, analyze, and present recent papers from the signal processing literature.

5 **Learning outcomes and competences:**

In this course, students will familiarize themselves with some current research topics in signal processing. They will learn to read and understand scientific publications and to critically evaluate results. Students will develop confidence in their ability to solve mathematical problems of analysis and design. They will be able to apply the principles they have learnt in this course to other areas.

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master’s Program Electrical Systems Engineering (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Peter Schreier</td></tr>
<tr><td>13</td><td>Other Notes:
<i>Remarks of course Topics in Signal Processing:</i>
Course Homepage
<code>http://sst.uni-paderborn.de/teaching/courses/</code>
Implementation
Lectures and tutorials with active student participation, student presentations
Teaching Material, Literature
References will be given in the first lecture.</td></tr>
</table>

Wireless Communications			
Wireless Communications			
Module number: M.048.92035	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92035 Wireless Communications	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Wireless Communications:
Recommended: Some basic knowledge in digital communication systems.

4 **Contents:**

Contents of the course Wireless Communications:
The course provides students with an insight into the techniques for reliable communication via time and/or frequency selective radio channels. To this end, the physical and statistical modeling of the radio channel is first presented, which forms the basis for understanding the transmission methods adapted to these channel conditions. Then, the main transmission and reception principles are presented, in particular the different diversity schemes:

- Time diversity: maximum ratio combiner, error rate calculation for coherent and incoherent reception, interleaving.
- Antenna diversity: SIMO, MISO and MIMO techniques
- Frequency diversity for frequency selective channels: Single-carrier techniques with sequence detection, band-spreading techniques, multicarrier transmission.

Emphasis will be placed on an illustrative derivation of the receiver principles as operations in a linear vector space. In addition, an insight into current cellular radio communication systems is given.
Table of contents

- Pulse amplitude modulation and orthogonal multi-pulse modulation
- Optimal detection
- Channel models for mobile radio
- Treatment of intersymbol interference
- Error rate on frequency nonselective Rayleigh Fading channel
- Diversity schemes: time, space, and frequency diversity
- Channel coding
- Cellular systems

5 **Learning outcomes and competences:**

Domain competence:
After completion of the course students will be able to

- Develop a discrete-time statistical channel model for a given physical description of a wireless communication channel
- Explain the techniques and algorithms used in the Physical Layer of a wireless communication system
- Understand the fundamental design options and decisions taken to realize reliable communication over time variant and frequency selective or nonselective fading channel
- Appreciate and categorize the techniques used in modern cellular communication systems to realize reliable communication
- Trade off the advantages and disadvantages of different transmission techniques with respect to bandwidth and power efficiency as well as number of users to be served
- Select and design an appropriate transmission technique for a wireless channel
- Simulate and analyze simple communication systems using modern software tools

Key qualifications:
The students

- Can transfer and apply the concept of linear vector spaces to signal processing tasks other than for wireless communications
- Can apply the skills about the generation of data, simulation of systems and analysis of experimental results using modern software tools, that have been acquired in this course, to other disciplines
- Can work cooperatively in a team and subdivide an overall task into manageable subtasks and work packages

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Häb-Umbach
13	**Other Notes:** *Remarks of course Wireless Communications:* **Course Homepage** `https://ei.uni-paderborn.de/en/nt/teaching/veranstaltungen/wireless-communications` Course script and summary slides are provided to the students. Exercises and solutions to exercises, as well as sample implementations of algorithms are provided to the students - Häb-Umbach, Reinhold: Wireless Communications (Lecture notes) - D. Tse: Fundamentals of Wireless Communications, Cambridge University Press, 2006 - K.D. Kammeyer: Nachrichtenuübertragung, Teubner, 2004 - P. Höher: Grundlagen der digitalen Informationsübertragung, Springer/Vieweg 2013

4.4 EE Catalogue Microelectronics

Advanced VLSI Design

Advanced VLSI Design

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92043	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92043 Advanced VLSI Design	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced VLSI Design:
Recommended: Fundamentals of Digital Circuits / Fundamentals of VLSI Design
Information: Unless otherwise specified, these are recommendations.

4 **Contents:**

Contents of the course Advanced VLSI Design:
Short Description
The course provides basic knowledge about the modern application-oriented modeling, simulation, analysis, and synthesis of digital systems at different abstraction levels to chip layout.
Contents
In today's practice, chip design consists of the combined application of various languages, methods, and tools for the modeling, simulation, and synthesis of electronic circuits. Along the modern abstraction-based design flow of digital systems (electronic system level to chip layout), the course provides basic knowledge of the main description languages and their application in modeling, simulation, analysis and synthesis. This includes basic principles and application of the IEEE standard system/hardware description languages SystemVerilog, SystemC, Verilog, and VHDL, in conjunction with additional formats, e.g., SDF and UPF for time and power annotation. For their application, the fundamental principles of test environments for simulation, timing and power analysis, logic synthesis and physical design of digital circuits. Exercises will provide hands-on labs based on commercial tools from Mentor Graphics, Synopsys and, Cadence Design Systems.

5	**Learning outcomes and competences:** **Domain competence:** After the course students are able • to model, simulate, analyze and synthesize simple digital circuits at different abstraction levels and • to apply the most important commercial tools for simulation, analysis and synthesis of digital circuits. **Key qualifications:** After the course students are able • to assess, select and apply modern digital circuit description languages for their different applications, • apply the different methods and tools in the modern VLSI design.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** apl. Prof. Dr. Wolfgang Müller

Assessments (6):

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

13	**Other Notes:** *Remarks of course Advanced VLSI Design:* **Course Homepage** `www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/advanced-vlsi-design` **Implementation** * Vorlesung mit Beamer und White-Board * Übungen mit Übungsblättern am Computer * Lecture with LCD projector and white board * Exercises with assignments and hands-on labs **Teaching Material, Literature** • Lecture notes and exercise sheets will be provided via PAUL • IEEE standard reference manuals: IEEE Std 1800/1685/1666/1364/1076/1801/1497 • Specific references for individual teaching units

Algorithms and Tools for Test and Diagnosis of Systems on a Chip

Algorithms and Tools for Test and Diagnosis of Systems on a Chip

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92007	180	6	summer- / winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92007 Algorithms and Tools for Test and Diagnosis of Systems on a Chip	2L 2Ex, WS+SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Recommended: VLSI Testing, (Introduction to Algorithms)

4 **Contents:**

Contents of the course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Short Description
The course “Algorithms and Tools for Test and Diagnosis of Systems on Chip” deals with advanced topics in test and diagnosis of integrated systems. The focus is on algorithms and tools for computer-aided preparation and application of test and diagnosis procedures.
** Contents**
Topics include but are not restricted to:

- Advanced techniques for built-in self-test and embedded test
- Built-in diagnosis
- Test of robust and self-adaptive systems
- Adaptive Testing

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the students will be able

- to describe recent approaches in test and diagnosis,
- to explain and apply the underlying models and algorithms,
- to explain the specific challenges of nanoscale integration and evaluate test strategies accordingly.

Key qualifications:
The students are able

- to apply their basic knowledge for studying and understanding new approaches from the state of the art literature,
- to present the new contents in a conference style presentation, and
- to describe the new contents in a scientific manuscript.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Sybille Hellebrand

13 **Other Notes:**

Remarks of course Algorithms and Tools for Test and Diagnosis of Systems on a Chip:
Module Homepage
`http://ei.uni-paderborn.de/en/electrical-engineering/date/teaching/electrical-engineering/overview`
Implementation

- Lecture based on slide presentation, extensions on blackboard
- Self-study on recent approaches based on recent conference and journal publications
- Oral presentation
- Manuscript

Teaching Material, Literature

- Lecture slides
- Additional material can be found in panda
- Michael L. Bushnell, Vishwani D. Agrawal, „Essentials of Electronic Testing for Digital, Memory, and Mixed-Signal VLSI Circuits,“ Kluwer Academic Publishers,2000
- Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, „VLSI Test Principles and Architectures: Design for Testability,“ Morgan Kaufmann Series in Systems on Silicon, ISBN: 0123705975
- Artikel aus Fachzeitschriften und Konferenzbänden / Articles from Journals and Conference Proceedings (e.g. IEEE Transactions on Computers, IEEE Transactions on CAD of Integrated Circuits and Systems, IEEE International Test Conference, etc.)

Analoge CMOS-Schaltkreise			
Analog CMOS ICs			
Module number: M.048.25008	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.25008 Analog CMOS ICs	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Analoge CMOS-Schaltkreise:
Recommended: Prior knowledge from the modules Higher Mathematics, Physics, and the Foundations of Electrical Engineering, Materials of Electrical Engineering, Semiconductor Devices, Signal Theory, System Theory.

4 **Contents:**

Contents of the course Analoge CMOS-Schaltkreise:
Short Description The course provides basic knowledge on analogue circuit technology with particular regard to complementary MOS transistors.
Contents
Based on simplified as well as advanced current-voltage characteristics of MOS transistors, analogue amplifier circuits are introduced and analyzed with respect of its DC behavior. Next, frequency performance, noise, effects of feed-backs, stability, non-linearity, and impacts of fabrication related asymmetries are considered. Further circuits such as oscillators, reference voltage sources, and switched capacitors are discussed. The course concludes with remarks on modeling and layout issues of basic devices.

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the students will be able to

- analyse the characteristics of analogue circuits using scientific methods
- and can make creative use of the acquired knowledge in the circuit design process.

Key qualifications:
The students

- make use of methodic knowledge for systematic problem analysis,
- consolidate their basic knowledge by practical training,
- enhance their creative abilities,
- and gain foreign language competences related to the field.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12 **Module coordinator:**

Prof. Dr. Andreas Thiede

13 **Other Notes:**

Remarks of course Analoge CMOS-Schaltkreise:
Course Homepage
`http://groups.upb.de/hfe/teaching/acc.html`
Implementation

- Lectures with black board presentation, supported by animated graphics and transparencies,
- Presence exercises with task sheets to be solved by the students together, supported by the teacher.

Teaching Material, Literature
A. Thiede, Analog CMOS Integrated Circuits, Vorlesungsskript Universität Paderborn A. Thiede, Analog CMOS Integrated Circuits, Lecture Script University Paderborn

- Razavi, B.: Design of Analog CMOS Integrated Circuits. McGraw Hill. 2001

Hochfrequenzleistungsverstärker			
Radio Frequency Power Amplifiers			
Module number: M.048.25015	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.25015 Radio Frequency Power Amplifiers	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Hochfrequenzleistungsverstärker:
Recommended: Prior knowledge from the modules Higher Mathematics, Physics, and the Foundations of Electrical Engineering, Materials of Electrical Engineering, Semiconductor Devices, Signal Theory, System Theory, High-Frequency Electronics.

4 **Contents:**

Contents of the course Hochfrequenzleistungsverstärker:
Short Description
The course provides basic knowledge on the design of integrated RF power amplifiers, in particular for mobile communication and sensor applications.
Contents
The course starts with an overview on analysis and simulation techniques for non-linear circuits. After that, first the conventional amplifier classes A, AB, B, and C are analysed and in particular overdrive effects are investigated. Second, the specific amplifier classes D, E,F, and S are introduced. Next, dedicated measures for the efficiency enhancement and linearization are described and particular amplifier architectures are presented. The course ends with an overview on semiconductor fabrication technologies for power amplifiers.

5	**Learning outcomes and competences:** **Domain competence:** After attending the course, the students will be able to • describe and analyse the performance of non-linear amplifiers, • distinguish, make dedicated use, and dimension power amplifiers of different classes, • take effective measures for efficiency enhancement and linearization, • and to select appropriate semiconductor fabricated technologies for given problems. **Key qualifications:** The students • can make use of methodic knowledge for systematic problem analysis, • include aspects of fabrication technology and economy into complex optimization problems, • get familiar with the CAD system ADS, which is commonly used in industry • and gain foreign language competences related to the field.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Andreas Thiede

Assessment details (item 6):

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

13	**Other Notes:** *Remarks of course Hochfrequenzleistungsverstärker:* **Course Homepage** http://groups.uni-paderborn.de/hfe/teaching/acc.html **Implementation** • Lectures with black board presentation, supported by animated graphics and transparencies • Presence exercises with task sheets to be solved by the students together, supported by the teacher, and partially using CAD software. **Teaching Material, Literature** A. Thiede, RF Power Amplifiers, Vorlesungsskript Universität Paderborn A. Thiede, RF Power Amplifiers, Lecture Script University Paderborn Steve C. Cripps, RF Power Amplifiers for Wireless Communications, Artech House, 1999 Stephen A. Maas, Nonlinear Microwave and RF Circuits, Artech House, 1997

Integrierte Schaltungen für die drahtlose Kommunikation			
Integrated Circuits for Wireless Communications			
Module number: M.048.25017	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.25017 Integrated Circuits for Wireless Communications	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Integrierte Schaltungen für die drahtlose Kommunikation:
Recommended: Lecture Schaltungstechnik rsp. Circuit and System Design. Helpful supplement: Lecture “Wireless Communications” of Prof. Hab-Umbach.

4 **Contents:**

Contents of the course Integrierte Schaltungen für die drahtlose Kommunikation:
Short Description
Mobile communications, wireless networks, and RFID technology are application examples of wireless communications. Wireless communications has found widespread use in everyday life and will become even more important in the future. The design of electronic circuits for radio frequencies requires a good system knowledge with respect to typical transmitter and receiver architectures in wireless communications, components, and radio signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required. Goal of the lecture is to convey a methodical approach to the design of integrated circuits for wireless communications. A part of the exercises will pertain to calculation of circuit design problems another will be performed in small teams as a hands-on exercise using modern IC design software.
Contents
The lecture deals with analysis and design of radio frequency integrated circuits for wireless communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures “Schaltungstechnik” rsp. “Circuit and System Design”. The following topics will be addressed:

- Transmitter and receiver architectures for wireless communications
- System Theory Basics
    - Signals and noise
    - Modulation and demodulation
    - Transmission properties of wireless communcations systems
- Semiconductor technologies and integrated high-frequency devices
- Amplifiers (low-noise and variable-gain amplifiers)
- Mixers
- Oscillators
- Frequency synthesizer PLLs

5 **Learning outcomes and competences:**

The students will be able

- to describe architectures and circuits of wireless communication systems
- to describe and calculate fundamental signal transmission properties of wireless systems
- to apply design methods to design components of radio frequency ICs

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Oral Examination	30-45 min	100%

7 **Study Achievement:**

none

8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr.-Ing. J. Christoph Scheytt
13	**Other Notes:** *Remarks of course Integrierte Schaltungen für die drahtlose Kommunikation:* **Course Homepage** `https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/integrierte-schaltungen-fuer-die-drahtlose-kommunikation/` **Implementation** • Lecture with Powerpoint presentation and handwritten mathematical derivations using tablet and beamer • Exercises partly as handwritten calculation exercises using tablet and beamer and partly as practical IC design exercises using IC design software **Teaching Material, Literature** Lecture slides and videos as well as exercise slides will be made available. • Behzad Razavi “RF Microelectronics”, Prentice Hall, 2011 • Thomas Lee “The Design of CMOS Radio-Frequency Integrated Circuits”, Cambridge University Press 2003

Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation			
Fast Integrated Circuits for Wireline Communications			
Module number: M.048.25019	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.25019 Fast Integrated Circuits for Wireline Communications	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:
Recommended: Module “Schaltungstechnik” of the Bachelor Electrical Engineering or module “Circuit and System Design” of the Master “Electrical Systems Engineering” or comparable modules / lectures

4 **Contents:**

Contents of the course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:
Short Description
Nowadays commercial fiber-optic communication systems reach very high data rates of 100 Gb/s per optical channel and several Tb/s in a single fiber. In a similar way very high data rates of more than 10 Gb/s occur at a single package pin of electronic chips. These signals are to be transmitted over printed circuit boards and inexpensive serial cables. In the future the progress of CMOS technology and communication technology will push speed of fiber-optic and wire-line communication continuously to ever higher data rates. The design of electronic circuits for high bandwidth rsp. data rates requires a good system knowledge with respect to typical transmitter and receiver architectures, components, and signal properties. Furthermore a thorough understanding of integrated circuit design as well as precise high-frequency modeling of passive and active devices are required. Goal of the lecture is to enable the student to utilize a methodological approach for the design of fast integrated electronic circuits for digital wired communications. A part of the exercises will be carried out using modern industry-standard IC design software.
Contents
The lecture deals with analysis and design of fast integrated electronic circuits for digital broadband communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures “Schaltungstechnik” rsp. “Circuit and System Design”. The lecture deals with:

- Transmitter and receiver architectures for fiber-optic communications
- Transmitter and receiver architectrues for chip-to-chip communications
- System design
- Semiconductor technology and integrated high-frequency devices
- Broadband amplifiers
- Current-mode logic
- Transmitter and receiver circuits
- PLLs for frequency synthesis and clock recovery
- Measurement methods

5 **Learning outcomes and competences:**

Domain competence:
The student will be able to:

- describe and analyze transmitter and receiver architectures for broadband communication links
- understand and describe semiconductor technologies and integrated high-frequency devices for broadband circuits
- to analyze circuit design techniques for transmitter and receiver circuits and describe ways to optimize them
- to describe circuits in PLL technique for frequency synthesis and clock recovery
- to describe measurement methods

Key qualifications:
The students will learn how different interdisciplinary scientific domains and their methods - like mathematical signal and system analysis, non-linear and linear circuit analysis, semiconductor physics, semiconductor devices and high-frequency engineering - are applied together for the development of communications application.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Oral Examination	30-45 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12 **Module coordinator:**

Prof. Dr.-Ing. J. Christoph Scheytt

13 **Other Notes:**

Remarks of course Schnelle integrierte Schaltungen für die leitungsgebundene Kommunikation:
Course Homepage
`https://www.hni.uni-paderborn.de/en/system-and-circuit-technology/teaching/fast-integrated-circuits-for-wireline-communications/`
Implementation
Lecture with Exercises (including computer-aided design using electronic design software)
Teaching Material, Literature
Handouts and literature references will be given in the lecture.

- E. Säckinger, “Broadband Circuits for Optical Fiber Communication”, Wiley, 2005
- B. Razavi, “Design of Integrated Circuits for Optical Communications”, McGraw-Hill, 2003

Comments
As part of the lecture a 2-day excursion to IHP Leibnizinstitute for High-Performance Microelectronics in Frankfurt (Oder) is offered which includes the visit of a modern chip fabrication facility (participation in the excursion is voluntary).

<table>
<tr><th colspan="4">Theorie und Anwendung von Phasenregelkreisen (PLL-Systemen)</th></tr>
<tr><td colspan="4">Theory and application of phase-locked loops (PLL Systems)</td></tr>
<tr><td>Module number:
M.048.25018</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
winter term</td></tr>
<tr><td>Language:
de</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
</table>

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.25018 Theory and Application of Phase-locked Loops (PLL Systems)	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Theorie und Anwendung von Phasenregelkreisen (PLL-Systemen):
Recommended: System theory, control and communication engineering

4 **Contents:**

Contents of the course Theorie und Anwendung von Phasenregelkreisen (PLL-Systemen):
Short Description
The aim of this module is to deliver insight into the complex and nonlinear behavior of a phase locked loop. Furthermore the theoretical basis of important aspects of the control loop applications for communications, instrumentation and energy technology (modulation, demodulation and frequency synthesis) will be demonstrated. The student is confronted with the fundamental problems of a digital-analog system. As part of this consideration different models will be developed and compared. Particular emphasis is placed on a practical analysis, and a practical design of the tested circuits. By simulating the nonlinear system the basic understanding of such structures shall be acquired. In addition to the theoretical basics different methods and algorithms shall be implemented by the students using Matlab.
Contents
Structure and properties of a phase-locked loop

- Principles of phase-locked loop (PLL)
- Analog and digital modules of the PLL
- Model - Switching differential equation - Linearization - Event-driven modeling

Design of a frequency synthesizer

- General conditions
- Concepts for parameter determination
- Design of the voltage controlled oscillator

5 **Learning outcomes and competences:**

Domain competence: After attending the course, the students will be able

- to describe the architecture and the functionality of the phase-locked loop,
- to perform a frequency synthesis, a phase- and frequency modulation and a clock synchronization using a phase-locked loop,
- to model a mixed-signal system in a linear and nonlinear way and
- to design the phase-locked loop in regard to the phase noise, the nonlinear behavior and the stability.

Key qualifications:
This module provides a deepening and widening of the modules electronics, control engineering, system theory, digital signal processing offered by the main study period of the bachelor's and master's degree. In this respect the described module is an example of the interdisciplinary deepening of the theoretical and practical aspects of the studies

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Dr.-Ing. Christian Hedayat
13	**Other Notes:** *Remarks of course Theorie und Anwendung von Phasenregelkreisen (PLL-Systemen):* **Course Homepage** `http://Sensorik.uni-paderborn.de/lehre` **Implementation** • Lecture based on slide presentation and on blackboard • Exercises based on exercise sheets with students presenting their own solutions **Teaching Material, Literature** • Best, R. E.: “Phase-Locked Loops - Design, Simulation and Application” • Gardner, F.: “Phase-Locked Techniques” • Encinas, J.: “Phase Locked Loops” • Hedayat, C. D. and Hachem, A. and Leduc, Y. and Benbassat, G.: “High-Level Modeling Applied to the Second-Order Charge-Pump PLL Circuit” • Acco, P. and Kennedy, M.P. and Mira, C. and Morley, B. and Frigyik, B.: “Behavioral modeling of charge pump phase locked loops” • Aktuelle Hinweise auf ergänzende Literatur und Lehrmaterialien auf der Webseite / Additional links to books and other material available at the webpage • Best, R. E.: “Phase-Locked Loops - Design, Simulation and Application” • Gardner, F.: “Phase-Locked Techniques” • Encinas, J.: “Phase Locked Loops” • Hedayat, C. D. and Hachem, A. and Leduc, Y. and Benbassat, G.: “High-Level Modeling Applied to the Second-Order Charge-Pump PLL Circuit” • Acco, P. and Kennedy, M.P. and Mira, C. and Morley, B. and Frigyik, B.: “Behavioral modeling of charge pump phase locked loops”

VLSI-Testing

VLSI-Testing

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.92027	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92027 VLSI Testing	2L 2Ex, WS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course VLSI Testing:
Recommended: Digital Design

4 **Contents:**

Contents of the course VLSI Testing:
Short Description
The course “VLSI Testing” focuses on techniques for detecting hardware defects in microelectronic circuits. Algorithms for test data generation and test response evaluation as well as hardware structures for design for test (DFT) and on-chip test implementation (BIST) are presented.
Contents
In detail the following topics are covered:

- Fault models
- Testability measures and design for test (DFT)
- Logic and fault simulation
- Automatic test pattern generation (ATPG)
- Built-in self-test (BIST), in particular test data compression and test response compaction
- Memory test

5 **Learning outcomes and competences:**

Domain competence:
After attending the course, the students will be able

- to describe fault models, DFT techniques, and test tools,
- to explain and apply the underlying models and algorithms for fault simulation and test generation,
- to analyze systems with respect to their testability and to derive appropriate test strategies.

Key qualifications:
The students

- are able to apply the practiced strategies for problem solving across varying disciplines,
- have experience in presenting their solutions to their fellow students, and
- know how to improve their competences by private study.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4, Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Sybille Hellebrand

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Other Notes:

Remarks of course VLSI Testing:
Course Homepage
`https://ei.uni-paderborn.de/en/electrical-engineering/date/teaching/electrical-engineering/overview`
Implementation

- Lecture based on slide presentation, extensions on blackboard
- Exercises in small groups based on exercise sheets with students presenting their own solutions
- Hands-on exercises using various software tools

Teaching Material, Literature
Additional material can be found in panda

- Michael L. Bushnell, Vishwani D. Agrawal, „Essentials of Electronic Testing for Digital, Memory, and Mixed-Signal VLSI Circuits,“Boston, Dordrecht, London: Kluwer Academic Publishers, 2000
- Laung-Terng Wang, Cheng-Wen Wu, Xiaoqing Wen, „VLSI Test Principles and Architectures: Design for Testability,“ Morgan Kaufmann Series in Systems on Silicon, ISBN: 0123705975

</td>
</tr>
</table>

4.5 EE Catalogue Optoelectronics

Fundamentals of Optics

Fundamentals of Optics

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.26007	180	6	summer- / winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.26007 Fundamentals of Optics	2L 2Ex, WS/SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Fundamentals of Optics:
Recommended:
It is strongly advised that the participants should have already passed a more introductory lecture such as “Fields and Waves”, “Electromagnetic Waves and Waveguides”, or any similar lectures on basic concepts in electromagnetic field propagation. Hence, participants should already be generally familiar with concepts such as Maxwell’s equations, constitutive relations, wave equation and plane-wave solutions to it, and Poynting vector.

4 **Contents:**

Contents of the course Fundamentals of Optics:

- Diffraction theory (describing beam propagation in homogenous media, considering different approximation regimes, e.g. Fresnel regime and Fraunhofer regime).
- Gaussian beams (including propagation of Gaussian beams and Gaussian beams in a resonator).
- Pulse propagation in dispersive homogenous media (considering effects like chirp and also specific case of a Gaussian pulse).
- Fourier optics (studying the transfer function of a thin lens, 2f setups and 4f setups for optical filtering).
- Optics in anisotropic media (studying the index ellipsoid and the normal modes of anisotropic crystals).

5	**Learning outcomes and competences:** After attending the lectures and the associated exercise sessions, the students will: • Be able to mathematically model problems in spatial and temporal propagation of electromagnetic/optical field in homogenous media • Gain physical intuition about the electromagnetic/optical beam and pulse propagation • Be able to identify the appropriate methods and approximations to solve field propagation problems
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Sina Saravi
13	**Other Notes:** **Module Homepage** Not yet available **Implementation** The theoretical concepts will be taught in a lecture format. The exercises consist of theoretical problems related to the concepts from the lecture, to be solved mathematically by the students, and later on the solutions will be presented in the exercise sessions. **Teaching Material, Literature** Lecture notes will be handed out; literature recommendations will be given in the first lecture.

Assessment table (item 6):

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

Advanced Quantum Optics

Advanced Quantum Optics

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.26010	180	6	summer- / winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.26010 Advanced Quantum Optics	2L 2Ex, WS/SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced Quantum Optics:
Recommended:
It is strongly advised that the participants should have already passed a more introductory lecture such as “Theoretical Quantum Optics”, “Quantum Optics”, or any similar lectures on basic concepts in quantum optics. Hence, participants should already be generally familiar with concepts such as field quantization, properties of nonclassical states of light such as Fock states and coherent states, quantum theory of light-matter interaction and Jaynes-Cummings model.

4 **Contents:**

Contents of the course Advanced Quantum Optics:

- Introducing density operators and quantum operations (Krauss maps)
- Derivation of Lindblad master equation from both a phenomenological approach and a derivation from first principles. Introducing Jump operators.
- Addressing various examples of an open quantum system involving a 2-level system and/or a lossy optical cavity.
- Introducing the physics and the mathematical methods for phase-space treatments in quantum optics, such as operator spaces and expansions in operator basis.
- Introducing various quasi-probability distributions (including the Wigner function) and investigating the fundamental relations between them, including specific examples for some basic states.
- Introducing general measurements.

5	**Learning outcomes and competences:** After attending the lectures and the associated exercise sessions, the students will: • Be able to mathematically model quantum optics problems in open quantum systems • Gain a basic yet fundamental understanding of phase-space methods in quantum optics • Be able to identify the appropriate methods and approximations to solve quantum optics problems in open quantum systems
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Sina Saravi
13	**Other Notes:** **Module Homepage** Not yet available **Implementation** The theoretical concepts will be taught in a lecture format. The exercises consist of theoretical problems related to the concepts from the lecture, to be solved mathematically by the students, and later on the solutions will be presented in the exercise sessions. **Teaching Material, Literature** Lecture notes will be handed out; literature recommendations will be given in the first lecture.

Assessments (6):

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

Hochfrequenzelektronik			
High-Frequency Electronics			
Module number: M.048.26001	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de / en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.26001 High-Frequency Electronics	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Hochfrequenzelektronik:
Recommended: Prior knowledge from the modules Higher Mathematics, Physics, and the Foundations of Electrical Engineering, Materials of Electrical Engineering, Semiconductor Devices, Signal Theory, System Theory, Introduction to High-Frequency Engineering.

4 **Contents:**

Contents of the course Hochfrequenzelektronik:
Short Description
The course High-Frequency Electronics provides necessary knowledge for the design of integrated high-frequency circuits ranging from device physics, semiconductor technology, high-frequency engineering, and packaging technology. Besides conveying new specialized knowledge, skills developed by various other courses are integrated, and thus students are directly prepared for a professional life in the field.
Contents
Starting from physically founded properties of different semiconductor systems, knowledge about the function, modeling, and fabrication of special high-frequency transistors is conveyed. Subsequently, all necessary steps of a high-frequency amplifier design are explained with respect to theoretical concepts and practical implementation. After that, further circuits such as broad-band amplifiers, oscillators, mixers and digital gates are presented. As currently most interesting applications, optoelectronic data transmission systems, mixed-signal systems such as ADC, DAC, digital synthesizers and PLL's, as well as millimeter wave transceivers are discussed. The course closes with an overview of high-frequency assembling and packaging technologies.

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Domain competence:
After attending the course, the students will be able to
select the most suitable semiconductor technology for a given problem,
run the complete design process of a high-frequency integrated circuit,
and to characterize fabricated samples.
Key qualifications:
The students
can use of methodic knowledge for systematic problem analysis,
include aspects of fabrication technology and economy into complex optimization problems,
get familiar with the CAD system ADS, which is commonly used in industry
and gain foreign language competences related to the field.</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Andreas Thiede</td></tr>
</table>

13 **Other Notes:**

Remarks of course Hochfrequenzelektronik:
Course Homepage
`http://groups.upb.de/hfe/teaching/hfe.html`
Implementation

- Vorlesungen mit überwiegendem Tafeleinsatz, unterstützt durch Animationen und Folien,
- Präsenzübungen mit Aufgabenblättern, deren Lösungen die Studierenden in der Übung gemeinsam und mit Unterstützung des Übungsleiters, teilweise unter Einsatz von CAD-Software erarbeiten.

Teaching Material, Literature
A. Thiede, High-Frequency Electronics, Vorlesungsskript Universität Paderborn A. Thiede, High-Frequency Electronics, Lecture Script University Paderborn References to continuative and deepening literature can be found in the respective sections of the script.

Optical Communication A

Optical Communication A

Module number:	Workload (h):	Credits:	Regular Cycle:
M.048.92019	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1.-3. Semester	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92019 Optical Communication A	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Communication A:
None

4 **Contents:**

Contents of the course Optical Communication A:

Short Description

The lecture Optical Communication A gives basic knowledge in Optical Communication and the components used in this field.

Contents

Maxwell's equations, wave propagation, polarization, dielectric slab and cylindrical waveguides, dispersion, laser, photodiodes, optical amplifiers, modulation, signal formats, optical receivers, noise, regenerators, wavelength division multiplex. Here the most important knowledge is taught.

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Professional Competence
After attending the course, the students will be able, in the taught subjects, to
describe, model and apply the function of components, systems and effects of optical communications and
apply knowledge of optoelectronics
(Soft) Skills
The students
are able to apply the knowledge and skills to a wide range of disciplines,
are able to make use of a methodical procedure when undertaking systematic analysis and
are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master’s Program Electrical Systems Engineering (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Reinhold Noé</td></tr>
</table>

13 **Other Notes:**

Remarks of course Optical Communication A:
Course Homepage
`http://ont.upb.de`
Teaching Material, Literature
Scripts, exercise sheets and advanced literature (excerpt):

- R. Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7
- Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag (modernes Nachschlagewerk) 2002
- D. As, Univ. Paderborn, Vorlesung Optoelektronik
- W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik
- G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991, (umfassend, viele Zwischenschritte fehlen)
- K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992
- H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter)
- Yariv, Optical Electronics, Holt, 1984 (und weitere Werke, sehr physikalisch, kaum Nachrichtentechnik)
- R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

<table>
<tr><th colspan="4">Optical Communication B</th></tr>
<tr><td colspan="4">Optical Communication B</td></tr>
<tr><td>Module number:
M.048.92020</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
summer term</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
</table>

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.92020 Optical Communication B	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Communication B:
None

4 **Contents:**

Contents of the course Optical Communication B:
Short Description
The lecture Optical Communication B gives some knowledge about mode coupling in Optical Communication and explains the function of many optical components.
Contents
Mode Coupling: Polarization mode dispersion, moden orthogonality, constant and periodic, co- and counterdirectional mode coupling, profiles of differential group delay, electrooptic effect. The function of many passive and active optical elements is thereby explained, among others amplitude and phase modulators, broadband and wavelength-selective couplers, Bragg gratings, polarization-maintaining fibers, polarization transformers, equalizers for polarization mode dispersion and chromatic dispersion.

<table>
<tr><td>5</td><td>

Learning outcomes and competences:

Professional Competence
After attending the course, the students will be able, in the taught subjects, to

- describe, model and apply the function of components, systems and effects of optical communications and
- apply knowledge of optoelectronics

(Soft) Skills
The students

- are able to apply the knowledge and skills to a wide range of disciplines,
- are able to make use of a methodical procedure when undertaking systematic analysis and
- are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves

</td></tr>
<tr><td>6</td><td>

Assessments:

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table>

</td></tr>
<tr><td>7</td><td>

Study Achievement:

none

</td></tr>
<tr><td>8</td><td>

Prerequisites for participation in examinations:

None

</td></tr>
<tr><td>9</td><td>

Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.

</td></tr>
<tr><td>10</td><td>

Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).

</td></tr>
<tr><td>11</td><td>

Reuse in degree courses or degree course versions :

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

</td></tr>
<tr><td>12</td><td>

Module coordinator:

Prof. Dr. Reinhold Noé

</td></tr>
</table>

13 **Other Notes:**

Remarks of course Optical Communication B:

Course Homepage

`http://ont.upb.de`

Teaching Material, Literature

Scripts, exercise sheets and advanced literature (excerpt):

- Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7
- Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag (modernes Nachschlagewerk) 2002
- D. As, Univ. Paderborn, Vorlesung Optoelektronik
- W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik
- G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991, (umfassend, viele Zwischenschritte fehlen)
- K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992
- H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter)
- Yariv, Optical Electronics, Holt, 1984 (und weitere Werke, sehr physikalisch, kaum Nachrichtentechnik)
- R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

<table>
<tr><th colspan="4">Optical Communication C</th></tr>
<tr><td colspan="4">Optical Communication C</td></tr>
<tr><td>Module number:
M.048.92021</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
winter term</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1.-3. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
WP</td></tr>
</table>

<table>
<tr><td>1</td><td>Module structure:
<table>
<tr><th></th><th>Course</th><th>form of teachin</th><th>contact-time (h)</th><th>self-study (h)</th><th>status (C/CE)</th><th>group size (TN)</th></tr>
<tr><td>a)</td><td>L.048.92021
Optical Communication C</td><td>2L
2Ex,
WS</td><td>60</td><td>120</td><td>C</td><td>30/30</td></tr>
</table>
</td></tr>
<tr><td>2</td><td>Options within the module:
None</td></tr>
<tr><td>3</td><td>Admission requirements:
None
<i>Prerequisites of course Optical Communication C:</i>
None</td></tr>
<tr><td>4</td><td>Contents:
<i>Contents of the course Optical Communication C:</i>
Short Description
The lecture Optical Communication C gives knowledge in various optical modulation and demodulation techniques.
Contents
Modulation Formats: Data transmission by differential binary and quaternary phase shift keying in the presence of optical amplifiers, polarization division multiplex, coherent optical data transmission, synchronous and asynchronous demodulation, coherent baseband receivers, polarization diversity, electronic compensators of optical distortions like electronic polarization control and electronic compensation of polarization mode dispersion and chromatic dispersion, phase noise, other modulation formats. Advanced modulation formats are an important possibility for the upgrading of high-performance optical information transmission systems.</td></tr>
</table>

5	**Learning outcomes and competences:** **Professional Competence** After attending the course, the students will be able, in the taught subjects, to • describe, model and apply the function of components, systems and effects of optical communications and • apply knowledge of optoelectronics **(Soft) Skills** The students • are able to apply the knowledge and skills to a wide range of disciplines, • are able to make use of a methodical procedure when undertaking systematic analysis and • are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Noé

Assessments (row 6):

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

13	**Other Notes:** *Remarks of course Optical Communication C:* **Teaching Material, Literature** Scripts, exercise sheets and advanced literature (excerpt): • Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7 • Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag (modernes Nachschlagewerk) 2002 • D. As, Univ. Paderborn, Vorlesung Optoelektronik • W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik • G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991, (umfassend, viele Zwischenschritte fehlen) • K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992 • H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter) • Yariv, Optical Electronics, Holt, 1984 (und weitere Werke, sehr physikalisch, kaum Nachrichtentechnik) • R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

Optical Communication D			
Optical Communication D			
Module number: M.048.92022	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92022 Optical Communication D	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optical Communication D:
None

4 **Contents:**

Contents of the course Optical Communication D:
Short Description
The lecture Optical Communication D gives knowledge about nonlinear optical effects in waveguides, their electronical detection, furthermore polarization scrambling.
Contents
Selected Topics in Optical Communication: Nonlinear distortions in glass fibers and their polarization dependence, electronic detection of linear optical distortions, polar-ization scrambling, ... Nonlinear distortions are important in practice and difficult to handle. The stu-dents should also prepare topics of their choice and present them to the others.

5	**Learning outcomes and competences:** **Professional Competence** After attending the course, the students will be able, in the taught subjects, to • describe, model and apply the function of components, systems and effects of optical communications and • apply knowledge of optoelectronics **(Soft) Skills** The students • are able to apply the knowledge and skills to a wide range of disciplines, • are able to make use of a methodical procedure when undertaking systematic analysis and • are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Master’s Program Electrical Systems Engineering (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)
12	**Module coordinator:** Prof. Dr. Reinhold Noé

Assessments (item 6):

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

13	**Other Notes:** *Remarks of course Optical Communication D:* **Course Homepage** `http://ont.upb.de` **Teaching Material, Literature** Scripts, exercise sheets and advanced literature (excerpt): • R. Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7 • Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag (modernes Nachschlagewerk) 2002 • D. As, Univ. Paderborn, Vorlesung Optoelektronik • W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik • G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991, (umfassend, viele Zwischenschritte fehlen) • K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992 • H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter) • Yariv, Optical Electronics, Holt, 1984 (und weitere Werke, sehr physikalisch, kaum Nachrichtentechnik) • R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

Optoelectronics			
Optoelectronics			
Module number: M.048.26011	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.048.26011 Optoelectronics	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Optoelectronics:
None

4 **Contents:**

Contents of the course Optoelectronics:
Short description
The lecture Optoelectronics covers the fundamental aspects of optoelectronic devices, starting with semiconductor materials and their interaction with light and photons, to the electronic aspects of the components, and finally to the use of quantum mechanical effects to optimise modern components for their respective areas of application, such as in lighting systems, renewable energy, broadband optical communication systems or in medical technology.
Contents
In the first part of the lecture, the basics of semiconductors (lattice structure, band structure, direct-indirect semiconductors, doping, degenerate and non-degenerate semiconductors, heterostructures, quantum effects in low-dimensional semiconductors) are recapitulated. The elementary interactions between light and semiconductors (absorption, stimulated emission, spontaneous emission) and the electronic aspects of the components (p-n junction, heterojunctions) are then covered. Finally, the most important devices such as solar cells, photodiodes, light-emitting diodes and semiconductor lasers are discussed in detail and their most important parameters and optimisation strategies are explained.

<table>
<tr><td>5</td><td>

Learning outcomes and competences:

Domain competence:
After attending the course, the students will be able to

- explain the basic physical properties of optoelectronic semiconductor devices based on classical and fundamental quantum mechanical descriptions,
- to describe the main concepts of optoelectronic semiconductor devices (photodiodes, solar cells, light emitting diodes, semiconductor lasers),
- categorize different device designs according to their application requirements.

Key qualifications:
The students

- can use of methodic knowledge for systematic problem analysis for a wide range of disciplines,
- will be in position to familiarise themselves independently with new generations of semiconductor devices, thanks to the comprehensive fundamental training received,
- get familiar to rate-equation models to simulate steady-state and dynamic characteristics in coupled systems,
- and gain foreign language competences related to the field.

</td></tr>
<tr><td>6</td><td>

Assessments:

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

</td></tr>
<tr><td>7</td><td>

Study Achievement:

none

</td></tr>
<tr><td>8</td><td>

Prerequisites for participation in examinations:

None

</td></tr>
<tr><td>9</td><td>

Prerequisites for assigning credits:

The credit points are awarded after the module examination (MAP) was passed.

</td></tr>
<tr><td>10</td><td>

Weighing for overall grade:

The module is weighted according to the number of credits (factor 1).

</td></tr>
<tr><td>11</td><td>

Reuse in degree courses or degree course versions :

BF Informationstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

</td></tr>
</table>

12	**Module coordinator:** Prof. Dr.-Ing. Nils Christopher Gerhardt
13	**Other Notes:** **Module Homepage** to be announced at the start of the lecture **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Lecture notes and handouts for the tutorial; literature references will be given in the first lecture

4.6 EE Catalogue Process Dynamics

Advanced Control			
Advanced Control			
Module number: M.048.92037	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92037 Advanced Control	2L 2Ex, SS	60	120	C	30/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced Control :
Recommended: Undergraduate-level systems theory and automatic control

4 **Contents:**

Contents of the course Advanced Control :
Short Description
This course builds on undergraduate-level systems theory and automatic control courses and focuses on the design of discrete-time control systems, using transfer function and state-space methods. The course is primarily intended to serve engineering students, but can also be useful to students in physics and other natural sciences.
Contents

- Discretization of dynamical systems
- Multivariable PI control
- Actuator constraints and anti-windup mechanism
- Optimal linear quadratic estimation
- Optimal linear quadratic control
- Basics of model predictive control for constrained systems

5 **Learning outcomes and competences:**

Domain competence:
After attending this course, students will be able to

- study the dynamics of feedback systems
- design appropriate control systems
- utilize engineering software tools to realize and test control designs

Key qualifications:
Students learn

- to use systematic analysis and synthesis methods that can be used in a variety of disciplines, both in engineering and natural sciences
- precise methods based on abstractions that can be used to further independent learning

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Erdal Kayacan

13	**Other Notes:** *Remarks of course Advanced Control :* **Course Homepage** `https://en.ei.uni-paderborn.de/rat` **Teaching Material, Literature** Book and general literature recommendations will be made during the active course time.

Advanced System Theory			
Advanced System Theory			
Module number: M.048.92001	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.92001 Advanced System Theory	2L 2Ex, WS	60	120	C	60/30

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Advanced System Theory:
Recommended:
Prerequisites are a basic understanding of differential equations, linear algebra, and Laplace transforms, as they are covered in a typical undergraduate course on system theory.

4 **Contents:**

Contents of the course Advanced System Theory:
Short Description
Building on an undergraduate system theory course, this course studies the dynamical behavior of linear systems with greater mathematical rigor. The course is primarily intended to serve students in engineering, but it can also be useful to students in physics and other natural sciences.
Contents

- System models and differential equations
- State-space and I/O descriptions
- Relations between internal and external descriptions
- Response of continuous- and discrete-time systems
- Stability, controllability, observability
- State-space realizations of external descriptions
- Feedback systems

5 **Learning outcomes and competences:**

After attending this course, students will be familiar with the most important concepts and results in linear system theory. Students will develop confidence in their ability to solve mathematical problems of analysis and design. Many of their timeless insights and intuitions about the dynamical behavior of systems will be drawn from this course. This course presents material broad enough so that students will have a clear understanding of the dynamical behavior of linear systems, including their power and limitations. This will allow students to apply the theory to other fields.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr. Erdal Kayacan

13 **Other Notes:**

Remarks of course Advanced System Theory:
Course Homepage
`https://en.ei.uni-paderborn.de/rat`
Implementation
Lectures and exercises (including some computer simulations) Panda course for communication and material distribution
Teaching Material, Literature
Handouts and exercise / tutorial questions; literature references will be given in the first lecture

Gekoppelte Felder

Coupled Fields

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.048.27028	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de	1.-3. Semester	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.27028 Coupled Fields	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Gekoppelte Felder:
Recommended: Basic knowledge from the area of classical field theory, for example from the modules “Field Theory”, “Electromagnetic Waves” and “Theoretical Electrical Engineering”.

4 **Contents:**

Contents of the course Gekoppelte Felder:
The focus of the course Coupled Fields is the classical field theory of interacting electromagnetic, thermal and mechanical phenomena as well as their application in sensors and actuators. After an introduction to the mathematical description of the individual fields, the following topics are covered:

- Electromechanical coupling based on examples in piezoelectricity, electrostriction and magnetostriction.
- Thermomechanical coupling such as thermoelasticity and lossy acoustic waves.
- Thermoelectric coupling, for example pyroelectricity.
- Phenomena with electromagnetic-thermal-mechanical coupling such as the photoacoustic effect. In addition to the description of the effects, analogies as well as similarities and differences are considered and aspects of numerical simulation are discussed.

5 **Learning outcomes and competences:**

After attending the course, students will be able to

- describe the discussed physical effects phenomenologically and with differential equations.
- interpret the results of numerical simulations of coupled fields and check them for plausibility.
- select suitable components for sensor and actuator applications of coupled fields.
- infer an acting physical effect from observations.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the examination will be conducted.

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

None

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination (MAP) was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4

12 **Module coordinator:**

Dr.-Ing. Leander Claes

13	**Other Notes:** **Module Homepage** `https://emt.upb.de` **Implementation** Lectures and exercises (including some computer simulations) **Teaching Material, Literature** Lecture slides and exercises will be provided. Additional literature references will be given throughout the course.

Geregelte Drehstromantriebe			
Controlled AC Drives			
Module number: M.048.27013	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.27013 Controlled AC Drives	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Geregelte Drehstromantriebe:
Recommended: It is strongly recommended that the students should have already finished a Bachelor course on the basics of electrical drives.

4 **Contents:**

Contents of the course Geregelte Drehstromantriebe:
Short Description
The course introduces the principle of flux-oriented control of three-phase AC motors, which is today's standard of electrical drives in industry. Unlike the course of the bachelor's program focus is put on the dynamics behavior and on the control structures. As most important examples, the permanent magnet synchronous motor and the induction motor are treated.
Contents

- AC drives: Synchronous and induction motor (structure, basic physical effects, modeling, equivalent circuit diagrams, characteristic curves, operation areas)
- Speed and torque control
- Space vector theory (fundamental wave, coordinate transformation)
- Principles of flux-oriented control
- Closed-loop control of current, torque and speed, design methods
- Direct Torque Control (DTC)
- Observers
- Applications in industry, road and rail vehicles

5	**Learning outcomes and competences:** **Domain competence:** • The students will understand the most important types of AC drives, their properties and should be able to select and to design such drives by themselves. **Key qualifications:** The students learn • to transfer the learned skills also to other disciplines, • extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises • learn strategies to acquire knowledge from literature and internet.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Dr.-Ing. Frank Schafmeister

Assessments (item 6):

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

13	**Other Notes:** *Remarks of course Geregelte Drehstromantriebe:* **ATTENTION - IMPORTANT NOTICE** The course doesn’t take place until further notice. Final Exam: in winter termin 2024/25! **Course Homepage** `http://ei.uni-paderborn.de/lea/` **Implementation** Parts of the course are organized as computer-based exercises. Teaching materials: Lecture notes. Other literature will be given in the lecture

Technische Akustik				
Technical Acoustics				
Module number: M.048.27022		**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: de		**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.27022 Technical Acoustics	2L 2Ex, WS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Technische Akustik:
None

4 **Contents:**

Contents of the course Technische Akustik:
Short Description
The course Technical Acoustics concentrates on teaching the basics of acoustics with a focus on modelling and simulation of sound propagation.
Contents:
The lecture Technical Acoustics is structured as follows

- Acoustic and sound field characteristics
- Fundamentals of wave propagation
- Hearing acoustics
- Wave equations
- Modelling
- Electro-acoustic as well as acoustic-electric couplings
- Material data
- Technical sound sources (properties)
- Sound field visualisation (for verification)

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Domain competence:
After attending the course, students are able to
describe sound propagation processes in solids, liquids and gases mathematically and analyse them by means of analytical or numerical simulation.
Key qualifications:
The Students
can apply the acquired knowledge and skills in an interdisciplinary manner and with complex issues,
are able to develop targeted solutions based on systematic problem analysis,
are capable of familiarising themselves with relevant fields of work due to the method-oriented knowledge transfer.</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
None</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination (MAP) was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Bernd Henning</td></tr>
</table>

13	**Other Notes:** *Remarks of course Technische Akustik:* **Course Homepage** `http://emt.upb.de` **Implementation** • Lectures with slide presentation of extensive contexts, • Practical work in groups using measurement techniques in the laboratory **Teaching Material, Literature** • Provision of a script; references to textbooks from the textbook collection will be announced.

Topics in Advanced Control			
Topics in Advanced Control			
Module number: M.048.27030	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.27030 Topics in Advanced Control	2L, 2S, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Topics in Advanced Control:
Recommended: System Theory and Automatic Control

4 **Contents:**

Contents of the course Topics in Advanced Control:
This course covers a selection of current topics in advanced control. The first part of the course will follow a regular lecture format, while the main part of the course will require active student participation and independent study of current research topics in advanced control. The course begins by briefly summarizing some key concepts in advanced control and discussing the spectrum between model-free and model-based control approaches. Then, specific topics will be introduced and students will select a research paper for their major study during the course. In addition, this course will provide an introduction to academic reading, writing and presentation as the semester progresses. From a methodological point of view, we will discuss advanced data-and model-based control methods, and in particular their application to real-world autonomous systems, robotics, and multi-agent systems. The selection of topics may change from year to year.

5 **Learning outcomes and competences:**

After completing the module, students will be able to:

- Explain the spectrum between model-free and model-based control.
- Autonomously gain expertise in a certain field of advanced control from the literature.
- Interpret the importance of publications in the field for the state-of-the-art.
- Apply the knowledge and techniques from this course to a wide range of disciplines.

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP) <table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or Oral Examination or Presentation</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table>
7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Erdal Kayacan

13	**Other Notes:** --- **ATTENTION - IMPORTANT NOTICE** The course will no longer take place from summer term 2025 until further notice. --- *Remarks of course Topics in Advanced Control:* --- **ATTENTION - IMPORTANT NOTICE** The course will no longer take place from summer semester 2025 until further notice. --- **Course Homepage:** `https://en.ei.uni-paderborn.de/de/rat` **Implementation:** • Lecture and seminar. • Presentation of literature. • Independent familiarization with a topic. • Exchange with other students and a supervisor from the group. • Final presentations by students.

Ultraschallmesstechnik			
Ultrasonic measurement technology			
Module number: M.048.27015	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: de	**Semester number:** 1.-3. Semester	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	L.048.27015 Ultrasonic Measurement Technology	2L 2Ex, SS	60	120	C	40/40

2 **Options within the module:**

None

3 **Admission requirements:**

None

Prerequisites of course Ultraschallmesstechnik:
None

4 **Contents:**

Contents of the course Ultraschallmesstechnik:
Short description
The course Ultrasonic Measurement Technology deals with the phenomena of propagation of mechanical waves in solids, liquids and gases. Based on this the most important acoustic measurement principles for the determination of acoustic material parameters, geometric and technical process parameters as well as their application in process and production engineering are described. The application of sound and ultrasound for non-destructive material diagnostics as well as for ultrasonic tomography are covered in detail.
Contents
The Ultrasonic Metrology lecture covers the following topics:

- Acoustic and sound field characteristics.
- Fundamentals of wave propagation
- Ultrasonic sensor design (experimental realization)
- Methods for measurement and visualization of ultrasonic fields (needle and membrane hydrophone, schlieren measuring station, laser vibrometry. . .)
- Metrological methods for acoustic material data determination (sound velocity, sound characteristic impedance. . .)
- Application of ultrasound for non-destructive testing (NDT) and acoustic emission analysis
- Application of ultrasound and in process measurement technology (distance, flow, level. . .)

5	**Learning outcomes and competences:** **Specialized competence:** After attending the course, students will be able to, • use ultrasound to determine acoustic and non-acoustic quantities. **Cross-disciplinary competencies:** The students • are able to apply the knowledge and skills across disciplines and to complex problems, • are able to develop targeted solutions on the basis of systematic problem analysis, • are able to familiarize themselves with tangential fields of work due to the method-oriented knowledge transfer.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or Oral Examination or Presentation	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** none
8	**Prerequisites for participation in examinations:** None
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** BF Automatisierungstechnik Lehramt BK affine Fächer Master v5, Masterstudiengang Computer Engineering v3 (CEMA v3), Masterstudiengang Computer Engineering v3 (CEMA v3), englisch, Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Elektrotechnik v4 (EMA v4), Masterstudiengang Elektrotechnik v5 (EMA v5), Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik, Masterstudiengang Wirtschaftsingenieurwesen Studienrichtung Elektrotechnik V4
12	**Module coordinator:** Prof. Dr. Bernd Henning

13 **Other Notes:**

Remarks of course Ultraschallmesstechnik:
Course Homepage
`http://emt.upb.de`
Methodical implementation

- Lectures with slide presentation of extensive correlations
- Practical work in groups using measurement techniques in the laboratory

Learning materials, references

- Provision of a script; references to textbooks from the textbook collection will be announced.

4.7 Computer Science Focus Area Classical and Quantum Algorithm Design

Advanced Algorithms			
Advanced Algorithms			
Module number: M.079.4002	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7011 Advanced Algorithms	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Advanced Algorithms:
Recommended Proficiencies
Willingness and ability to learn the creative process of algorithm design and efficiency analysis using mathematical methods. Basic Knowledge of some basic algorithms and data structures and their analyses is assumed.

4 **Contents:**

Contents of the course Advanced Algorithms:
This course presents advanced algorithms and algorithmic paradigms for fundamental problems. More precisely, methods like randomization and derandomization as well as concepts for approximation and online algorithms will be presented by illustrating their usefulness for important algorithmic problems. In all cases, the correctness and runtime will be rigorously analyzed.

- Randomized algorithmens and derandomization, for example, randomized rounding
- Online algorithms, for example, scheduling algorithms
- Approximation algorithms, for example, NP-hard problems

5	**Learning outcomes and competences:** Students will be able to • understand and apply basic analytical techniques, • explain and apply basic algorithmic approaches, • judge which effects these approaches have, and • know the limits of using these approaches.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Christian Scheideler
13	**Other Notes:** *Remarks of course Advanced Algorithms:* **Implementation Method** The lecture uses a blackboard and slides as well as small exercises for the students during the lecture. It will be supported by tutorial groups. Students have the opportunity in tutorial groups to work on problems in a group and to discuss solutions of the exercise sheets with the tutors. **Learning Material, Literature** • Slides of the lecture; exercise sheets • Additional literature will be announced in the course

Advanced Distributed Algorithms and Data Structures

Advanced Distributed Algorithms and Data Structures

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4006	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7012 Advanced Distributed Algorithms and Data Structures	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Advanced Distributed Algorithms and Data Structures:
Recommended Proficiencies
Algorithms and data structures, distributed algorithms and data structures

4 **Contents:**

Contents of the course Advanced Distributed Algorithms and Data Structures:
After a short introduction of the foundations of graph and network theory as well as distributed programs, the lecture presents advanced methods in the area of distributed algorithms and data structures. Topics covered in the course are access control, synchronization, consensus, information dissemination, hybrid networks, scheduling, and optimization. In addition to presenting solutions to these topics, also concrete applications will be presented.
The lecture gives an introduction to state-of-the-art advanced distributed algorithms and data structures. In addition to the presentation of the corresponding protocols, their correctness and efficienty will be shown in a rigorous way. The lecture is structured as follows:

- Introduction
- Fooundations of graph and network theory
- Access control
- Synchronization
- Consensus
- Information dissemination
- Hybrid networks
- Scheduling
- Optimization

In addition to presenting solution to these topics, also concrete applications will be presented.

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Students will be able to
• understand and apply basic analytical techniques,
• explain and use basic algorithmic approaches,
• judge which effects these approaches have, and
• know the limits of using these approaches.</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or oral examination or report</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
<table>
<tr><th>zu</th><th>Type of achievement</th><th>Duration or Scope</th><th>SL / QT</th></tr>
<tr><td>a)</td><td>Assignments, course paper or progress reports</td><td></td><td>CA</td></tr>
</table></td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
Passing of course achievement</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Christian Scheideler</td></tr>
<tr><td>13</td><td>Other Notes:
<i>Remarks of course Advanced Distributed Algorithms and Data Structures:</i>
Implementation Method
The lecture uses a blackboard and slides as well as small exercises for the students during the lecture. It will be supported by tutorial groups. Students have the opportunity in tutorial groups to work on problems in a group and to discuss solutions of the exercise sheets with the tutors.
Learning Material, Literature
• Slides of the lecture; exercise sheets
• Additional literature will be announced in the course</td></tr>
</table>

Algorithms for Highly Complex Virtual Scenes			
Algorithms for Highly Complex Virtual Scenes			
Module number: M.079.4009	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:**	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	L.079.05756 Algorithms for Highly Complex Virtual Scenes	L3 Ex2	75	105	CE	40/20

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Algorithms for Highly Complex Virtual Scenes:
Recommended Proficiencies
Willingness and ability to learn the creative process of algorithm design and efficiency analysis using mathematical methods. Basic Knowledge of some basic algorithms and data structures and their analyses is assumed.

4 **Contents:**

Contents of the course Algorithms for Highly Complex Virtual Scenes:
Walkthrough systems allow viewing and walking through a virtual 3D scene and finds application in architecture programs, simulations or games. The efficiency of real-time rendering algorithms is crucial for a smooth and fast visualization of the virtual 3D scene in a walkthrough system. There are different algorithmic approaches to reduce highly complex 3D geometric data and to achieve a rendering of the scene in real time. The lecture introduces algorithmic approaches in the areas of visibility culling, simplification, level of detail, image-based rendering and further approaches.

- Introduction: walkthrough problem
- Data structures: kd-tree, BSP-tree, octree, loose octree
- Level of detail: adaptive LOD management, mesh simplification, progressive meshes
- Visibility culling: view frustum culling, potentially visible sets (PVS), dynamic analysis of PVS, Hierarchical z-buffer, hierarchical occlusion maps, aspect graph, visibility space partition
- Replacement: color cubes, randomized z-buffer, hierarchical image caching
- Parallel rendering: classification and modeling, parallel rendering as a sorting problem, hybrid sort-first/sort-last rendering

5	**Learning outcomes and competences:** The students can apply fundamental techniques in the area of real time rendering of virtual 3D scenes. They can decide in which virtual 3D scene which algorithm is most appropriate. They can adapt algorithms to a new situation. **Non-cognitive Skills** • Attitude • Self-monitoring
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination	90-120 min or 40 min	100%

The responsible lecturer announces type and duration of assessment modalities in the first three weeks of the lecture period at latest.

7	**Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Written exercises		CA

Within the first three weeks of the lecture period each respective lecturer will specify the manner in which the course achievement will be conducted.

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Informatik v3
12	**Module coordinator:** Dr. Matthias Fischer

13	**Other Notes:** *Remarks of course Algorithms for Highly Complex Virtual Scenes:* **Implementation method** • Lecture with beamer and blackboard • Practice in small groups • Expected activities of the students: Collaboration in presence exercises Homework • exercise sheets, sample solutions are presented in central exercises • In exercises and homework sheets and teh analysis of algorithms of selected examples are practiced. **Learning Material, Literature** • Standard textbooks, slides of the lecture, exercise sheets • Real-Time Rendering; Tomas Akenine-Möller, Eric Haines; AK Peters, 2002. • Level of Detail for 3D Graphics; David Luebke, Martin Reddy, Jonathan D. Cohen; Morgan Kaufmann Publishers, 2002.

Foundations of Cryptography			
Foundations of Cryptography			
Module number: M.079.4020	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7043 Foundations of Cryptography	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Foundations of Cryptography:
Recommended Proficiencies
Basic Knowledge in IT-Security and cryptography useful but not necessary, basic concepts of complexity theory and probability theory

4 **Contents:**

Contents of the course Foundations of Cryptography:
Cryptography is an important basic technique in IT security. Internet protocols such as TLS are based on cryptographic primitives such as key exchange, encryption and signatures. In this lecture, important basic concepts of modern cryptography will be introduced. These include encryption schemes, digital signatures, identification protocols, and multiparty computations. In all cases, formal security definitions are presented and, starting from mathematically precise assumptions, provably secure constructions are developed. An essential aspect of the lecture is the construction of efficient and secure cryptographic methods from assumptions that are as general as possible. Contents include:

- Symmetric and asymmetric encryption.
- Pseudorandom functions, one-way functions, permutations with trapdoors
- Hash functions and authentication codes
- Digital signatures, one-time signatures and random oracles.
- Identification protocols, Σ protocols.
- Security concepts such as unforgeable signatures and CPA- and CCA-secure encryption schemes.

5 **Learning outcomes and competences:**

Upon completion of the module, students will be able to:

- understand, explain and apply concepts and methods of modern cryptography.
- select appropriate cryptographic methods according to the security requirements of an application, e.g. distinguish where encryption methods and where authentication methods are appropriate.
- combine primitives of cryptography according to application requirements and prove the security of the combination.
- define new security concepts and design cryptographic methods that satisfy those concepts.
- understand and independently develop security proofs.
- acquire latest research results in the field of cryptography by reading scientific papers.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Johannes Blömer

13	**Other Notes:** *Remarks of course Foundations of Cryptography:* **Implementation method** Basic concepts are presented in a lecture. In addition, theoretical concepts are deepened in tutorials in small groups. Written exercises and reading groups will be used to practice the practical application of these concepts. **Learning Material, Literature** • Oded Gorldreich, Foundations of Cryptography I,II, • Jonathan Katz, Yehuda Lindell, Introduction to Modern Cryptogtraphy • Slides from the lectures • Lecture notes

Introduction to Quantum Computation			
Introduction to Quantum Computation			
Module number: M.079.4059	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7044 Introduction to Quantum Computation	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Introduction to Quantum Computation:
Recommended Proficiencies
Linear Algebra, algorithms

4 **Contents:**

Contents of the course Introduction to Quantum Computation:
This lecture introduces the fundamental concepts of quantum computation and information from a computer science perspective. This includes an introduction to quantum mechanics, quantum entanglement, quantum algorithms, quantum error correction, and quantum information theory.

- Quantum mechanics
- Quantum entanglement
- Quantum algorithms
- Quantum error correction
- Quantum information

5 **Learning outcomes and competences:**

Students are able to:

- Describe and apply the postulates of quantum mechanics
- Understand the use of entanglement as a resource
- Design and analyze fundamental quantum algorithms
- Apply the theory of error-correcting codes
- Understand and apply basic quantum information theory concepts such as entropy

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Sevag Gharibian

13 **Other Notes:**

Remarks of course Introduction to Quantum Computation:
Implementation method
Slides and blackboard writing. All important concepts and techniques are further deepened with examples in exercises.
Learning Material, Literature

- Michael A. Nielsen, Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press
- Lecture slides, exercises

Post-Quantum Cryptography			
Post-Quantum Cryptography			
Module number: M.079.4089	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7015 Post-Quantum Cryptography	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Post-Quantum Cryptography:
Recommended Proficiencies
Basics of cryptography and complexity theory

4 **Contents:**

Contents of the course Post-Quantum Cryptography:
IT security is largely based on modern cryptographic methods. These include many methods of so-called public-key cryptography such as the RSA and Elgamal encryption methods, the RSA signature method, and the various variants of the Digital Signature Algorithm (DSA). In 1994, Peter Shor presented an efficient algorithm for computing prime factorization of integers and for computing discrete logarithms in finite groups. Thus, all the aforementioned methods of public-key cryptography are insecure if quantum computers of sufficient size and complexity can be realized. It is therefore important to develop alternatives to classical public-key methods that, at least according to current research, cannot be broken by quantum computers. Important candidates (and some close to standardization) for such post-quantum secure methods rely on techniques of error-correcting codes and the geometry of numbers. In this lecture, we will present and discuss important candidates for post-quantum secure methods. The course includes the following contents:

- introduction to codes, lattices and discretised Gaussian distributions
- lattice and code based enryption
- lattice based signatures
- lattices and zero-knowledge proofs
- lattice based group signatures

5	**Learning outcomes and competences:** Students will be able to • understand and explain the difference between classical and post-quantum security. • explain the importance of post-quantum cryptography for selected applications. • explain and apply concepts from the field of geometry of numbers and error-correcting codes. • explain important constructions from post-quantum cryptography and prove their security. • explain security assumptions from post-quantum cryptography and apply them to new post-quantum primitives.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:**
8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Johannes Blömer
13	**Other Notes:** *Remarks of course Post-Quantum Cryptography:* **Implementation Method** Basic concepts are presented in a lecture. In addition, theoretical concepts are deepened in tutorials in small groups as well as in written exercises. **Learning Material, Literature** References to current learning materials will be given in the lectures.

Assessments (6):

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

Study Achievement (7):

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

Quantum Algorithms			
Quantum Algorithms			
Module number: M.079.4072	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7014 Quantum Algorithms	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Quantum Algorithms:
Recommended Proficiencies
Linear Algebra, Quantum Computing

4 **Contents:**

Contents of the course Quantum Algorithms:
This lecture covers quantum algorithms from a computer science perspective. Topics include quantum circuits (e.g. Solovay-Kitaev theorem), quantum algorithms for algebraic problems (e.g. Hidden Subgroup problem), quantum walks, quantum query complexity, and adiabatic quantum computing.

- Quantum circuits
- Algebraic problems
- Quantum walks
- Query complexity
- Adiabatic computation

5 **Learning outcomes and competences:**

Students are able to:

- Describe universal gate sets
- Develop Quantum Fourier-Transform based algorithms
- Develop quantum walk-based algorithms
- Apply the quantum adiabatic theorem
- Give quantum query lower bounds

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Sevag Gharibian
13	**Other Notes:** *Remarks of course Quantum Algorithms:* **Implementation method** Slides and blackboard writing. All important concepts and techniques are further deepened with examples in exercises. **Learning Material, Literature** • Michael A. Nielsen, Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press • Andrew M. Childs, Wim van Dam, Quantum algorithms for algebraic problems, Reviews of Modern Physics, volume 82, 2010 • Lecture slides, exercises

Quantum Complexity Theory

Quantum Complexity Theory

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4063	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7046 Quantum Complexity Theory	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Quantum Complexity Theory:
Recommended Proficiencies
Linear Algebra, Quantum Computing

4 **Contents:**

Contents of the course Quantum Complexity Theory:
This lecture provides a brief review of introductory quantum computation, and subsequently moves into quantum complexity theory. Beginning to advanced topics will be covered, including quantum analogues of P and NP (denoted BQP, QCMA, and QMA), quantum satisfiability problems, quantum interactive proofs, and tensor networks. Along the way, semidefinite programming will be introduced as an important tool.

- Complexity classes BQP, QCMA, QMA
- Quantum algorithms for linear system solving
- Quantum Satisfiability Problems
- Quantum Interactive Proofs
- Semidefinite Programming

5 **Learning outcomes and competences:**

Students will be able to

- Distinguish language classes from promise classes
- Define fundamental quantum complexity classes, such as BQP and QMA
- Prove BQP-hardness results via polynomial-time reductions
- Prove QMA-hardness results via polynomial-time reductions
- Apply semidefinite programming to analyze quantum interactive proofs

6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Sevag Gharibian
13	**Other Notes:** *Remarks of course Quantum Complexity Theory:* **Implementation method** Slides and blackboard writing. All important concepts and techniques are further deepened with examples in exercises. **Learning Material, Literature** • Michael A. Nielsen, Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press • S. Gharibian, Y. Huang, Z. Landau, S. W. Shin, Quantum Hamiltonian Complexity, Foundations and Trends in Theoretical Computer Science • Lecture slides, assignments

Quantum Information

Quantum Information

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4090	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
de	1-3	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7040 Quantum Information	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Quantum Information:
Recommended Proficiencies
Linear Algebra

4 **Contents:**

Contents of the course Quantum Information:
Over the last century, Quantum mechanics has had profound impacts on both fundamental science and technology. The emerging field of Quantum Information Theory studies a paradigm for information processing empowered by quantum mechanics. This field has demonstrated that quantum information processing can outperform its classical counterpart and is a revolutionary direction to investigate future information technologies. Quantum Information Science incorporates techniques from computer science, mathematics, and physics.
Of particular interest is quantum entanglement, which is the phenomenon that occurs when a group of particles is generated or interacts in a way such that the state of each particle cannot be described independently of the others, even when the particles are separated by arbitrarily large distances. Entanglement is a primary feature of quantum mechanics not present in classical physics and it is a resource behind most modern quantum technologies, such as quantum computers. This lecture introduces the advance concepts of quantum communication and information.
The contents include:

- Entanglement of two- and many-body systems
- Quantum information processing and applications
- Measures of Entanglement, Distance and Fidelity
- Higher local dimensions (qubits vs qudits)
- Quantum channels
- Classical and quantum error correcting codes and their differences

5 **Learning outcomes and competences:**

Students learn cutting-edge concepts at the intersection of computer science and quantum mechanics. This lecture equips students with advanced, interdisciplinary technical proficiency, enabling them to pursue careers in analysis intensive industries, technology start-ups, or research and development roles in leading technology companies or academia. To achieve this, the students get familiar with the basics of quantum mechanics and the related algebra. Furthermore, they will be able to:

- understand the underlying concepts of entangled systems (two-body and many-body),
- understand the fundamental idea of maximally entangled systems, classify and characterise them for practical applications,
- describe the basic notion of higher local dimension particles (qubits vs qudits),
- apply the theory of classical and quantum error correcting codes, and study their differences,
- to work on interdisciplinary topics and, in particular, to acquire the basics of different disciplines.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Dr. Zahra Raissi

13	**Other Notes:** *Remarks of course Quantum Information:* **Implementation Method** Theoretical foundations and concepts will be taught in the form of lectures and deepened in practical exercise courses, group work as well as individual assignments. **Learning Material, Literature** • Michael A. Nielsen, Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, 2000. • F. J. MacWilliams and N. J. A. Sloane. The Theory of Error-Correcting Codes, North-Holland Mathematical Library. North-Holland, Amesterdam, 1977. ISBN 9780444851932. • Ingemar Bengtsson and Karol Zyczkowski, Geometry of quantum states: an introduction to quantum entanglement, Cambridge university press, 2006, ISBN 9780511535048. • Lecture slides • Exercises

4.8 Computer Science Focus Area Computer and Communication Systems

Advanced Distributed Algorithms and Data Structures			
Advanced Distributed Algorithms and Data Structures			
Module number: M.079.4006	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7012 Advanced Distributed Algorithms and Data Structures	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Advanced Distributed Algorithms and Data Structures:
Recommended Proficiencies
Algorithms and data structures, distributed algorithms and data structures

4	**Contents:** *Contents of the course Advanced Distributed Algorithms and Data Structures:* After a short introduction of the foundations of graph and network theory as well as distributed programs, the lecture presents advanced methods in the area of distributed algorithms and data structures. Topics covered in the course are access control, synchronization, consensus, information dissemination, hybrid networks, scheduling, and optimization. In addition to presenting solutions to these topics, also concrete applications will be presented. The lecture gives an introduction to state-of-the-art advanced distributed algorithms and data structures. In addition to the presentation of the corresponding protocols, their correctness and efficienty will be shown in a rigorous way. The lecture is structured as follows: • Introduction • Fooundations of graph and network theory • Access control • Synchronization • Consensus • Information dissemination • Hybrid networks • Scheduling • Optimization In addition to presenting solution to these topics, also concrete applications will be presented.
5	**Learning outcomes and competences:** Students will be able to • understand and apply basic analytical techniques, • explain and use basic algorithmic approaches, • judge which effects these approaches have, and • know the limits of using these approaches.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:**
8	**Prerequisites for participation in examinations:** Passing of course achievement

Assessments (6):

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

Study Achievement (7):

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Christian Scheideler
13	**Other Notes:** *Remarks of course Advanced Distributed Algorithms and Data Structures:* **Implementation Method** The lecture uses a blackboard and slides as well as small exercises for the students during the lecture. It will be supported by tutorial groups. Students have the opportunity in tutorial groups to work on problems in a group and to discuss solutions of the exercise sheets with the tutors. **Learning Material, Literature** • Slides of the lecture; exercise sheets • Additional literature will be announced in the course

Reconfigurable Computing			
Reconfigurable Computing			
Module number: M.079.4043	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7034 Reconfigurable Computing	L2 Ex3	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Reconfigurable Computing:
Recommended Proficiencies
Knowledge of the Bachelor-level courses Digital Design, Programming, and Data Structures and Algorithms are beneficial.

4 **Contents:**

Contents of the course Reconfigurable Computing:
The course Reconfigurable Computing introduces into the field of computing with reprogrammable hardware structures. Computing systems built from reprogrammable hardware structures do not rely on a fixed hardware, but adapt their hardware architecture to the application under execution. The field was formed in the early 1990s when Field-programmable Gate Arrays (FPGAs) became commercially available that were powerful enough to be used for computing. Today, FPGA-based high-performance systems have outperformed state-of-the-art computers for many problems including database search, genomic sequence scanning, and cryptography. In embedded systems, FPGAs accelerate system functions, reduce system cost and energy consumption, and enable hardware-on-demand functionality. The course covers the following topics:

- Introduction to reconfigurable computing
- Evolution of programmable hardware devices
- FPGA architectures
- Computer-aided design for FPGAs
- High-level languages for programming FPGAs
- Application domains for FPGAs
- Comparison of devices, technologies, and reconfigurable systems

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Students will be able to
compare different reprogrammable hardware devices and describe their historical development,
name the design steps and problems when designing with FPGAs,
analyse algorithms for the design steps and apply them to examples,
compare and evaluate current approaches to programming FPGAs,
justify the suitability of different reprogrammable hardware components for different areas of application, and
implement functions of medium complexity with modern FPGA design tools.</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or oral examination or report</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:<table><tr><th>zu</th><th>Type of achievement</th><th>Duration or Scope</th><th>SL / QT</th></tr><tr><td>a)</td><td>Assignments, course paper or progress reports</td><td></td><td>CA</td></tr></table></td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
Passing of course achievement</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Marco Platzner</td></tr>
</table>

13	**Other Notes:** *Remarks of course Reconfigurable Computing:* **Implementation Method** The course consists of a lecture, and pencil&paper as well as practical exercises. The lecture is held with a beamer and blackboard. In the pencil&paper exercises, problems are handed out and their solutions are presented and discussed in a practice session. In addition, quizzes are offered for self-assessments. In the practical exercises, a tutorial on the design with FPGAs is carried out and then tasks are handed out, which are implemented as design or programming examples in groups of one to three participants. **Learning Material, Literature** • Lecture slides, assignment sheets for paper&pencil exercises, quizzes • Tutorial, assignment sheets for design and programming examples, technical documentation • Selected scientific articles • Additional literature will be announced in the course.

4.9 Computer Science Focus Area Data Science and Intelligent Systems

Advanced Algorithms

Advanced Algorithms

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4002	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7011 Advanced Algorithms	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Advanced Algorithms:
Recommended Proficiencies
Willingness and ability to learn the creative process of algorithm design and efficiency analysis using mathematical methods. Basic Knowledge of some basic algorithms and data structures and their analyses is assumed.

4 **Contents:**

Contents of the course Advanced Algorithms:
This course presents advanced algorithms and algorithmic paradigms for fundamental problems. More precisely, methods like randomization and derandomization as well as concepts for approximation and online algorithms will be presented by illustrating their usefulness for important algorithmic problems. In all cases, the correctness and runtime will be rigorously analyzed.

- Randomized algorithmens and derandomization, for example, randomized rounding
- Online algorithms, for example, scheduling algorithms
- Approximation algorithms, for example, NP-hard problems

5 **Learning outcomes and competences:**

Students will be able to

- understand and apply basic analytical techniques,
- explain and apply basic algorithmic approaches,
- judge which effects these approaches have, and
- know the limits of using these approaches.

<table>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or oral examination or report</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
<table>
<tr><th>zu</th><th>Type of achievement</th><th>Duration or Scope</th><th>SL / QT</th></tr>
<tr><td>a)</td><td>Assignments, course paper or progress reports</td><td></td><td>CA</td></tr>
</table></td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
Passing of course achievement</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Christian Scheideler</td></tr>
<tr><td>13</td><td>Other Notes:
<i>Remarks of course Advanced Algorithms:</i>
Implementation Method
The lecture uses a blackboard and slides as well as small exercises for the students during the lecture. It will be supported by tutorial groups. Students have the opportunity in tutorial groups to work on problems in a group and to discuss solutions of the exercise sheets with the tutors.
Learning Material, Literature
• Slides of the lecture; exercise sheets
• Additional literature will be announced in the course</td></tr>
</table>

Advanced Distributed Algorithms and Data Structures			
Advanced Distributed Algorithms and Data Structures			
Module number: M.079.4006	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7012 Advanced Distributed Algorithms and Data Structures	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Advanced Distributed Algorithms and Data Structures:
Recommended Proficiencies
Algorithms and data structures, distributed algorithms and data structures

4 **Contents:**

Contents of the course Advanced Distributed Algorithms and Data Structures:
After a short introduction of the foundations of graph and network theory as well as distributed programs, the lecture presents advanced methods in the area of distributed algorithms and data structures. Topics covered in the course are access control, synchronization, consensus, information dissemination, hybrid networks, scheduling, and optimization. In addition to presenting solutions to these topics, also concrete applications will be presented.
The lecture gives an introduction to state-of-the-art advanced distributed algorithms and data structures. In addition to the presentation of the corresponding protocols, their correctness and efficienty will be shown in a rigorous way. The lecture is structured as follows:

- Introduction
- Fooundations of graph and network theory
- Access control
- Synchronization
- Consensus
- Information dissemination
- Hybrid networks
- Scheduling
- Optimization

In addition to presenting solution to these topics, also concrete applications will be presented.

5	**Learning outcomes and competences:** Students will be able to • understand and apply basic analytical techniques, • explain and use basic algorithmic approaches, • judge which effects these approaches have, and • know the limits of using these approaches.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Christian Scheideler
13	**Other Notes:** *Remarks of course Advanced Distributed Algorithms and Data Structures:* **Implementation Method** The lecture uses a blackboard and slides as well as small exercises for the students during the lecture. It will be supported by tutorial groups. Students have the opportunity in tutorial groups to work on problems in a group and to discuss solutions of the exercise sheets with the tutors. **Learning Material, Literature** • Slides of the lecture; exercise sheets • Additional literature will be announced in the course

Data Science for Software Engineering			
Data Science for Software Engineering			
Module number: M.079.4101	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	Data Science for Software Engineering	L2 Ex3	75	105	CE	30

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Data Science for Software Engineering:
Recommended Proficiencies
Good programming skills using Java and/or Python is helpful to make the assignments. Basic background on machine learning is helpful to understand some of the Data Science concepts.

4 **Contents:**

Contents of the course Data Science for Software Engineering:
Software engineers deal with software repositories in their daily work, such as when they develop source code in version control systems, or post issues in issue trackers, or communicate through emails in mailing lists, or discuss in forums and blogs. The big amount of data in software repositories, their continuous evolution, complexity and heterogeneity present a challenge for software engineers. In the past years, researchers proposed approaches that use techniques from the data science to support software engineers. This course will explain the application of data science techniques on software repositories to achieve common software engineering tasks. The course includes the following topics:

- Types and structure of software repositories.
- Clustering of source code.
- Natural language processing pipeline.
- Topic modeling.
- Word embedding.
- Information retrieval.
- Supervised machine learning.
- Statistical analysis.

Concepts are discussed in the lectures and applied using a set of group assignments to analyze opensource systems, ans achieve certain software architecture and maintenance tasks.

5	**Learning outcomes and competences:** Students will be able to • Clarify and discuss types and structure of software repositories. • Clarify and discuss main concepts of data science techniques, and their application on sotware repositories. • Apply data science techniques on large-scale software repositories. • Derive useful implications from the analysis results. • Summarize and report analysis results in a scientific format. • Work in teams. • Write scientific reports • Present research results
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:**
8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v3, Masterstudiengang Informatik v4
12	**Module coordinator:** Dr. Mohamed Aboubakr Mohamed Soliman

Assessments (6):

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination	90-120 min or 30-45 min	100%

Study Achievement (7):

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments and short presentations		CA

13	**Other Notes:** *Remarks of course Data Science for Software Engineering:* **Implementation Method** The course focus on the application of data science methods in software engineering more than the mathematical background of data science methods. The main concepts of methods are conveyed through a presentation as part of a lecture and the application of methods is further investigated through group assignments and presentations. **Learning Material, Literature** Beside the slides, further learning materials from prominent publications in the software engineering literature will be provided for each topic.

Data Science in Industrial Applications

Data Science in Industrial Applications

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4075	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7053 Data Science in Industrial Applications	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

4 **Contents:**

Contents of the course Data Science in Industrial Applications:
The course “Data Science in Industrial Applications” deals with the methods and techniques of data analysis in an industrial context. Students learn basic concepts of data analysis and how to apply them in practice.
The increasing networking of machines, sensors and IT systems in the context of Industry 4.0 has led to a rapid increase in the amount of available data. The analysis of data offers enormous potential for the automation of cognitive tasks, the optimization of processes and the further creation of value from data. The lecture will provide an overview of the challenges and solution approaches for the industrial application of Data Science. This includes the integration of industrial data sources from the field, the IT landscape in manufacturing companies and the setup of (Big Data) infrastructure, typical algorithms in the area of time series processing, optimization or image processing as well as the embedding in business processes. Theoretical and methodological basics, concepts and tools are introduced during the lecture and applied in small groups based on a case study as well as deepened in home exercises. The theoretical concepts for the planning, introduction and implementation of Industrial Data Science in theory are supplemented by practical real-life examples.

5 **Learning outcomes and competences:**

Students

- understand the challenges of applying Data Science in industrial applications,
- have an overview of typical application examples,
- are able to apply methods of signal processing, machine learning, and statistics to industrial problems,
- are able to plan the implementation of data acquisition, data architecture, and integration into business processes,
- are able to develop solutions on their own as well as in cooperation,
- are proficient in basic project management skills.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr.-Ing. Roman Dumitrescu

13

Other Notes:

Remarks of course Data Science in Industrial Applications:

Implementation Method

The course includes lectures (slide-based), exercises (interactive), and project work. In the lectures, the theoretical basics of data analysis in an industrial context are taught. In the exercises, students have the opportunity to apply what they have learned by means of practical tasks. The project work offers the students the opportunity to apply the learned knowledge in a larger context. In the exercise, knowledge transfer and application of the concepts take place in a case study in the form of workshops and implementation of an industrial analytics application in independent group work.

Learning Material, Literature

A more detailed list of the lecture materials and references will be given in the first course. A good first insight into the subject area is given by:

- Wiendahl, Hans-Peter; Wiendahl, Hans-Hermann (2019): Betriebsorganisation für Ingenieure. 9., vollständig überarbeitete Auflage. München: Hanser (Hanser eLibrary).
- Zahn, Erich; Schmid, Uwe (1996): Grundlagen und operatives Produktionsmanagement. Mit 42 Tabellen. Stuttgart: Lucius & Lucius (Grundwissen der Ökonomik Betriebswirtschaftslehre, 1).
- Günther Schuh; Achim Kampker: Strategie und Management produzierender Unternehmen: Handbuch Produktion und Management 1 (VDI-Buch) (German Edition).
- Schuh, Günther; Riesener, Michael (2018): Produktkomplexität managen. Strategien - Methoden - Tools. 3., vollständig überarbeitete Auflage. München: Hanser (Hanser eLibrary). Online verfügbar unter http://www.hanser-elibrary.com/doi/book/10.3139/9783446453340.
- Schuh, Günther; Schmidt, Carsten (2014): Produktionsmanagement. DOI: 10.1007/978-3-642-54288-6.
- Bishop, Christopher M. (2006): Pattern recognition and machine learning. New York: Springer (Information science and statistics).
- Cao, Longbing (2018): Data Science. In: ACM Comput. Surv. 50 (3), S. 1–42. DOI: 10.1145/3076253.
- Geron, Aurelien (2019): Hands-On Machine Learning with Scikit-Learn and TensorFlow: O'Reilly Media.
- Goodfellow, Ian; Bengio, Yoshua; Courville, Aaron (2016): Deep Learning. MIT Press.
- James, Gareth; Witten, Daniela; Hastie, Trevor; Tibshirani, Robert (2013): An Introduction to Statistical Learning. New York, NY: Springer New York (103).
- Mitchell, Tom M. (1997): Machine Learning. New York: McGraw-Hill (McGraw-Hill series in computer science).
- Runkler, Thomas A. (2016): Data Analytics. Wiesbaden: Springer Fachmedien Wiesbaden.
- Russell, Stuart (2009): Artificial Intelligence: A Modern Approach. 3rd Edition. Pearson.
- Schutt, Rachel; O'Neil, Cathy (2013): Doing data science. Straight talk from the frontline. 1. ed. Beijing: O'Reilly.

Explainable Artificial Intelligence

Explainable Artificial Intelligence

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4091	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7025 Explainable Artificial Intelligence	L2 Ex1 P2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Explainable Artificial Intelligence:
Recommended Proficiencies
Basic knowledge in machine learning and programming

4 **Contents:**

Contents of the course Explainable Artificial Intelligence:
Explaining the predictions of machine learning models is important in an increasing number of applications. For example, bank customers would like to know why their loan was denied; machine learning engineers would like to debug and improve their models; managers would like to ensure regulatory compliance. This course aims to explain the predictions of machine learning models and introduces different explanation methods to do so. Explanation methods can be distinguished whether they are specific to a certain model or model-agnostic and whether they explain an individual prediction or the entire model.

- Introduction (e.g., importance of interpretability, evaluation of interpretability, datasets used in case studies)
- Interpretable models (e.g., linear regression, logistic regression, decision trees, decision rules)
- Global model-agnostic methods (e.g., partial dependence plots, permutation feature importance, global surrogate models)
- Local model-agnostic methods (e.g., LIME, Anchors, SHAP, counterfactual explanations)
- Model-specific methods (e.g., for neural networks)

5 **Learning outcomes and competences:**

After completing the module, students will be able to

- recognize and discuss the importance of interpretability
- explain and apply important explanation methods (e.g., interpretable models, model-agnostic methods, and model-specific methods)
- recognize characteristics of datasets, machine learning tasks, and machine learning models in application problems and argue which explanation method is appropriate for a given problem
- implement simple explanation methods from scratch
- extend and modify existing explanation methods
- discuss problems and proposed solutions with experts in the field
- read and discuss research literature in the area of XAI

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Dr. Stefan Heindorf

13	**Other Notes:** *Remarks of course Explainable Artificial Intelligence:* **Implementation method** Slides and blackboard writing. Important concepts and techniques will be practiced through exercises in the lecture room and tutorials, and applied in a mini-project. **Learning Material, Literature** • Slides • Exercises • Book: Christoph Molnar. Interpretable machine learning. 2020. • Additional material and literature will be announced in the course.

Foundations of Knowledge Graphs

Foundations of Knowledge Graphs

Module number: M.079.4054	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7026 Foundations of Knowledge Graphs	L2 Ex3	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Foundations of Knowledge Graphs:
Recommended Proficiencies
Knowledge of Graph theory and logics is beneficial.

4 **Contents:**

Contents of the course Foundations of Knowledge Graphs:
Knowledge graphs are used in an increasing number of applications. Large organisations such as Google Yahoo! and the BBC rely on these technologies to organise and manage the access to the the large amounts of data they manage. This lecture aims to present approaches for building, storing, integrating and using knowledge graphs. We will being by studying knowledge extraction techniques for unstructured data. These include named entity recognition, disambiguation and relation extraction. Technologies for storing and knowledge (e.g., triple stores) will be presented subsequently. Time-efficient and accurate approaches for knowledge integration and link prediction will be followed by a series of applications for knowledge graphs.

- Semantic networks
- Property graphs
- RDF graphs
- Query languages (e.g., Cypher, SPARQL)
- Knowledge extraction from text
- Knowledge extraction from semi-structured data
- Link discovery
- Machine learning approaches for link discovery
- Link prediction and tensor factorization

<table>
<tr><td>5</td><td>Learning outcomes and competences:
The students can carry out the following after the completion of the module:
• Model knowledge graphs;
• Describe the formal semantics of modeling languages;
• Create formal ontologies and check them for consistency;
• Model efficient imperative and descriptive languages;
• Train and execute knowledge extraction models.</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
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Passing of course achievement</td></tr>
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<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Axel-Cyrille Ngonga Ngomo</td></tr>
</table>

13	**Other Notes:** *Remarks of course Foundations of Knowledge Graphs:* **Implementation method** 2 SWS of lectures within which the students will be presented with novel content weekly. The lecture will be self-contained with the students being presented with the premises for understanding particular aspects of knowledge graphs as well as with the corresponding conclusions and approaches derived from these premises. 1 SWS of exercises allow the students to deal with the concepts presented in the lecture through formal analysis and programming. The 2 SWS of mini-projects ensure that the students obtain a holistic understanding of the concepts learned by applying them to a more complex task than the one addressed in the exercises. **Learning Material, Literature** Slides, homework assignments

Machine Learning for Biometrics			
Machine Learning for Biometrics			
Module number: M.079.4088	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7024 Machine Learning for Biometrics	L2 Ex3	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

4 **Contents:**

Contents of the course Machine Learning for Biometrics:
Biometric verification is defined as the automated recognition of individuals based on their behavioral or biological characteristics. The course will give an overview of modern biometric systems and specifically address their functionality and challenges. For this purpose, various approaches of machine learning will be introduced, which aim at enabling reliable biometric recognition (e.g. by means of face recognition). At the same time, biometric applications place very specific requirements on the underlying algorithms. The course will specifically address these requirements and how they can be met algorithmically and in the algorithmic learning process. This includes the topics of privacy, fairness, explainability, uncertainties, efficiency, attacks and their automated detection.
The course includes the following content:

- Biometric systems, operation modes, and evaluation
- Recap on traditional and deep learning
- Face, Iris, and fingerprint recognition
- Soft-biometrics and privacy
- Fairness and bias in biometric systems
- Explainability and confidence in biometric systems
- Biometric sample quality
- Efficient biometric systems
- Presentation attacks and detection
- Multi-biometric fusion
- Biometric indexing

5 **Learning outcomes and competences:**

Students will be able to

- independently evaluate biometric systems,
- train biometric recognition models for different modalities,
- automatically detect biometric attacks and make systems robust against such attacks,
- explain various challenges of biometric systems and name solution strategies to counter them,
- name and explain open research questions in biometrics.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

none

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Dr.-Ing. Philipp Terhörst

13	**Other Notes:** *Remarks of course Machine Learning for Biometrics:* **Implementation Method** First, students are given an overview of biometrics and its applications and basic functionalities. Then, required concepts of machine learning are introduced in a compact way. These will be applied and developed in context when dealing with specific biometric requirements. Parallel to the lecture, the theoretical concepts are practiced in the exercises using facial data. This is done in the form of short hand-written and implementation tasks. **Learning Material, Literature** • Anil K. Jain, Patrick Flynn, and Arun A. Ross. 2010. Handbook of Biometrics (1st. ed.). Springer Publishing Company, Incorporated. • Further literature will be announced in the lecture.

Multi-Objective Optimisation			
Multi-Objective Optimisation			
Module number: M.079.4095	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	Multi-Objective Optimisation	L3 Ex2	75	105	CE	30/15

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Multi-Objective Optimisation:
Recommended Proficiencies
Solid basic knowledge of algorithms and data structures, mathematics, as well as basic knowledge of optimization are beneficial.

4 **Contents:**

Contents of the course Multi-Objective Optimisation:
Optimization problems are ubiquitous, and we all (approximately) solve them in everyday life, such as when finding routes with Google Maps to quickly get from point A to point B or deciding on a checkout lane with the shortest waiting queue (shortest expected waiting time) at the supermarket. However, optimization problems are rarely single-criteria. Instead, they are typically multi-criteria in nature, with the individual objectives usually conflicting with each other. For example, in route planning, the distance traveled may be relevant (shorter is better), and fuel consumption may also be a consideration (lower is better). The shortest route may lead through the city center with many stop-and-go maneuvers at red lights, especially during peak hours. On the other hand, a longer route around the city may consume less fuel. Accordingly, the goal in multi-objective optimization is to find a set of optimal compromise solutions.
This course provides a comprehensive introduction to multi-objective optimization and the associated challenges. In addition to classical general approaches, exact methods for selected combinatorial optimization problems are presented, along with heuristic (nature-inspired) methods. The course also covers heuristic solution approaches for problems with more than three criteria (many-objective optimization).

5	**Learning outcomes and competences:** Students will be able to • Explain, implement, and apply important exact algorithms for multi-criteria minimum spanning tree problems and multi-criteria shortest path problems • Understand the limitations of exact algorithms for multi-criteria problems • Explain and apply biologically inspired heuristics for multi-objective problems • Assess, evaluate, and visualize the quality of computed results from multi-criteria algorithms • Understand the challenges of problems with more than three criteria and explain solution approaches
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	90-120 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v3, Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Heike Trautmann

13	**Other Notes:** *Remarks of course Multi-Objective Optimisation:* **Implementation Method** Slide-based lecture with interspersed assignments. In the tutorial, the knowledge transfer and application of what has been learned takes place in both theoretical and practical assignments. **Learning Material, Literature** • Deb, Kalyanmoy. „Multi-Objective Optimization Using Evolutionary Algorithms“. • Ehrgott, Matthias. Multicriteria Optimization. Bd. 491. Lecture Notes in Economics and Mathematical Systems. Berlin, Heidelberg: Springer, 2000. • Additional literature will be announced in the course.

Unsupervised Learning and Evolutionary Optimisation Using R

Unsupervised Learning and Evolutionary Optimisation Using R

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4093	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7027 Unsupervised Learning and Evolutionary Optimisation Using R	L3 Ex2	75	105	C	70

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Unsupervised Learning and Evolutionary Optimisation Using R:
Recommended Proficiencies

- Basic knowledge and interest in mathematics, statistics and probability theory
- Basic knowledge of programming

4 **Contents:**

Contents of the course Unsupervised Learning and Evolutionary Optimisation Using R:
The course includes the formal and applied concepts of unsupervised machine learning and its implementation in the statistical programming language R.
In particular, the following topics are covered in a theoretical and applied manner:

- Introduction to the statistical programming language R
- Data pre-processing and quality aspects of data
- (Stream) clustering techniques
- Dimensionality reduction techniques
- Basic principles of evolutionary optimisation, both single- and multi-objective
- Practical application of the methods using R in individual and group work

5	**Learning outcomes and competences:** After completing the module, students will be able to ... • properly assess data quality and select suitable techniques for data pre-processing • explain and apply core methods of unsupervised learning • understand the basic principles of evolutionary optimisation methods • competently apply techniques to assess the quality of optimisation procedures • use the statistical software R for statistical data analysis, unsupervised learning and evolutionary optimisation in a competent manner • analyse problems in a team and present practice-relevant solutions
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	90-120 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Heike Trautmann

<table>
<tr><td>13</td><td>Other Notes:

<i>Remarks of course Unsupervised Learning and Evolutionary Optimisation Using R:</i>
Implementation Method
An introduction to the statistical programming language R is given compactly in the first weeks of the course. Methods of unsupervised machine learning are covered within lecture presentations interleaved with interactive exercises. Methods understanding will be further deepened in tutorials focusing both on theory as well as application-oriented tasks using R.
Learning Material, Literature
Recommended for the statistical programming language R:
Hadley Wickham & Garrett Grolemund (2023). R for Data Science: Import, Tidy, Transform, Visualize, and Model Data. 2nd ed. O'Reilly
Torsten Hothorn and Brian S. Everitt (2014). A Handbook of Statistical Analyses Using R. Chapman & Hall/CRC Press, 3rd edition, 2014.
C. Heumann, M. Schomaker, and Shalabh. Introduction to Statistics and Data Analysis With Exercises, Solutions and Applications in R. Springer, 2017.
The methods sections are based on a variety of references which will be announced in the lecture.</td></tr>
</table>

4.10 Computer Science Focus Area Security

Advanced Distributed Algorithms and Data Structures			
Advanced Distributed Algorithms and Data Structures			
Module number: M.079.4006	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7012 Advanced Distributed Algorithms and Data Structures	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Advanced Distributed Algorithms and Data Structures:
Recommended Proficiencies
Algorithms and data structures, distributed algorithms and data structures

4 **Contents:**

Contents of the course Advanced Distributed Algorithms and Data Structures:
After a short introduction of the foundations of graph and network theory as well as distributed programs, the lecture presents advanced methods in the area of distributed algorithms and data structures. Topics covered in the course are access control, synchronization, consensus, information dissemination, hybrid networks, scheduling, and optimization. In addition to presenting solutions to these topics, also concrete applications will be presented.
The lecture gives an introduction to state-of-the-art advanced distributed algorithms and data structures. In addition to the presentation of the corresponding protocols, their correctness and efficienty will be shown in a rigorous way. The lecture is structured as follows:

- Introduction
- Fooundations of graph and network theory
- Access control
- Synchronization
- Consensus
- Information dissemination
- Hybrid networks
- Scheduling
- Optimization

In addition to presenting solution to these topics, also concrete applications will be presented.

5 **Learning outcomes and competences:**

Students will be able to

- understand and apply basic analytical techniques,
- explain and use basic algorithmic approaches,
- judge which effects these approaches have, and
- know the limits of using these approaches.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Christian Scheideler
13	**Other Notes:** *Remarks of course Advanced Distributed Algorithms and Data Structures:* **Implementation Method** The lecture uses a blackboard and slides as well as small exercises for the students during the lecture. It will be supported by tutorial groups. Students have the opportunity in tutorial groups to work on problems in a group and to discuss solutions of the exercise sheets with the tutors. **Learning Material, Literature** • Slides of the lecture; exercise sheets • Additional literature will be announced in the course

Designing code analyses for large-scale software systems 1			
Designing code analyses for large-scale software systems 1			
Module number: M.079.4070	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7041 Designing code analyses for large-scale software systems 1	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Designing code analyses for large-scale software systems 1:
Recommended Proficiencies
A mature understanding of the Java programming languages and object-oriented programming will be helpful.

4 **Contents:**

Contents of the course Designing code analyses for large-scale software systems 1:
Static code analysis is frequently used to find programming mistakes automatically, by searching for suspicious anti-patterns in a program's code. This course will explain how to design static code analysis that are inter-procedural, i.e., consider the whole program, across procedure boundaries. Designing such analyses is challenging, as they need to handle millions of program statements efficiently and precisely. Example applications are drawn from the area of IT security.
This course is part of a combination DECA 1/2. In DECA 2 we will be covering current approaches directly our of research. We strongly recommend attending DECA 1 before DECA 2.
Topics covered include:

- Type systems and flow-insensitive, contraint-based analysis
- Lattices and fixed points
- Intra-procedural flow-sensitive static code analysis
- Interval analysis, widening and narrowing
- Call-graph construction
- Pointer Analysis
- Inter-procedural program analysis
- Call-strings approach to context-sensitive analysis
- Functional approach to context-sensitive analysis
- Value-based termination, VASCO
- Distributive analyses using IFDS
- Sensible arrangements of Flow Functions
- Distributive analyses using IDE

Throughout, we will discuss applications to software security.

5 **Learning outcomes and competences:**

Upon completion of the module, students will be able to

- name and distinguish the most important concepts and algorithms in the field of static program analysis
- explain the effects of various alternative design decisions when designing a static program analysis
- implement and apply simple static program analyses themselves and illustrate their function
- contrast and compare data structures and algorithms for static program analysis
- evaluate and justify the applicability of certain analysis procedures to specific application contexts, and
- develop tools for static program analysis by composing several analysis methods.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** zu | **Type of achievement** | **Duration or Scope** | **SL / QT** a) | Assignments, course paper or progress reports | | CA
8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Eric Bodden
13	**Other Notes:** *Remarks of course Designing code analyses for large-scale software systems 1:* **Implementation method** Lectures and group exercises as well as practical programming labs using worldwide leading frameworks for static code analysis **Learning Material, Literature** • Thomas Reps, Susan Horwitz, and Mooly Sagiv. 1995. Precise interprocedural dataflow analysis via graph reachability. POPL ’95 • Shmuel Sagiv, Thomas W. Reps, and Susan Horwitz. 1995. Precise Interprocedural Dataflow Analysis with Applications to Constant Propagation. TAPSOFT ’95 • Akash Lal, Thomas Reps, and Gogul Balakrishnan. 2005. Extended weighted pushdown systems. CAV 2005 • Nomair A. Naeem, Ondrej Lhoták, and Jonathan Rodriguez. 2010. Practical extensions to the IFDS algorithm. CC 2010 • Yannis Smaragdakis, Martin Bravenboer, and Ondrej Lhoták. 2011. Pick your contexts well: understanding object-sensitivity. POPL 2011 • Eric Bodden. 2012. Inter-procedural data-flow analysis with IFDS/IDE and Soot. SOAP 2012 • Rohan Padhye, Uday P. Khedker. Interprocedural Data Flow Analysis in Soot using Value Contexts. SOAP 2013

Designing code analyses for large-scale software systems 2			
Designing code analyses for large-scale software systems 2			
Module number: M.079.4071	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 2-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7042 Designing code analyses for large-scale software systems 2	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Designing code analyses for large-scale software systems 2:
Recommended Proficiencies
We strongly recommend that attendees have completed DECA 1 beforehand. A mature understanding of the Java and/or C++ programming languages and object-oriented programming will be helpful.

4 **Contents:**

Contents of the course Designing code analyses for large-scale software systems 2:
Static code analysis has the goal of finding programming mistakes automatically, by searching for suspicious anti-patterns in a program's code. This course will explain how to design static code analysis that are inter-procedural, i.e., consider the whole program, across procedure boundaries. Designing such analyses is challenging, as they need to handle millions of program statements efficiently and precisely. Example applications are drawn from the area of IT security.
This course builds on the DECA 1 course. In DECA 2, we discuss novel concepts directly from research, for example so-called demand-driven analyses, which are characterized by a more precise and at the same time more efficient analysis, but also pushdown systems, which provide a allow elegant modeling and at the same time fast execution of program analyses. Last but not least, we explain current solutions to practical problems in static analysis, such as the use of reflection and native code.
Topics covered include:

- Program analysis of software product lines
- Modeling call stacks and field accesses with Pushdown Systems
- Modeling auxiliary analysis information with Weighted Pushdown Systems
- Efficiency and precision gains through Demand-driven Program Analysis
- Synchronized Pushdown Systems in the Boomerang framework
- Applied Android code analysis with FlowDroid
- Dealing with Reflection through TamiFlex
- Hybrid static and dynamic analysis with Harvester
- Learning source, sink and sanitizer definitions with SWAN and SWAN Assist
- Explainable static analysis

5 **Learning outcomes and competences:**

Upon completion of the module, students will be able to

- name and explain the most important challenges in inter-procedural static program analysis
- name and distinguish current methods in the field of inter-procedural static program analysis
- explain the implications of various alternative design decisions in the design of an inter-procedural static program analysis.
- contrast and compare data structures and algorithms for inter-procedural static program analysis and
- evaluate and justify the applicability of current analysis techniques in a broad range of application contexts.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Eric Bodden

13 **Other Notes:**

Remarks of course Designing code analyses for large-scale software systems 2:
Implementation method
Lectures and group exercises as well as programming exercises using widely used real-world static analysis frameworks (e.g. Soot, Phasar, FlowDroid)
Learning Material, Literature

- Context-, Flow-, and Field-sensitive Data-flow Analysis Using Synchronized Pushdown Systems (Johannes Späth, Karim Ali, Eric Bodden), In Proceedings of the ACM SIGPLAN Symposium on Principles of Programming Languages, pages 48:1–48:29, 3(POPL), 2019.
- FlowDroid: Precise Context, Flow, Field, Object-sensitive and Lifecycle-aware Taint Analysis for Android Apps (Steven Arzt, Siegfried Rasthofer, Christian Fritz, Eric Bodden, Alexandre Bartel, Jacques Klein, Yves Le Traon, Damien Octeau, Patrick McDaniel), In Proceedings of the 35th ACM SIGPLAN Conference on Programming Language Design and Implementation, pages 259–269, PLDI ’14, ACM, 2014.
- Codebase-Adaptive Detection of Security-Relevant Methods (Goran Piskachev, Lisa Nguyen Quang Do, Eric Bodden), In ACM SIGSOFT International Symposium on Software Testing and Analysis (ISSTA), 2019.
- Taming Reflection: Aiding Static Analysis in the Presence of Reflection and Custom Class Loaders (Eric Bodden, Andreas Sewe, Jan Sinschek, Hela Oueslati, Mira Mezini), In ICSE ’11: International Conference on Software Engineering, pages 241–250, ACM, 2011.

Foundations of Cryptography			
Foundations of Cryptography			
Module number: M.079.4020	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7043 Foundations of Cryptography	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Foundations of Cryptography:
Recommended Proficiencies
Basic Knowledge in IT-Security and cryptography useful but not necessary, basic concepts of complexity theory and probability theory

4 **Contents:**

Contents of the course Foundations of Cryptography:
Cryptography is an important basic technique in IT security. Internet protocols such as TLS are based on cryptographic primitives such as key exchange, encryption and signatures. In this lecture, important basic concepts of modern cryptography will be introduced. These include encryption schemes, digital signatures, identification protocols, and multiparty computations. In all cases, formal security definitions are presented and, starting from mathematically precise assumptions, provably secure constructions are developed. An essential aspect of the lecture is the construction of efficient and secure cryptographic methods from assumptions that are as general as possible. Contents include:

- Symmetric and asymmetric encryption.
- Pseudorandom functions, one-way functions, permutations with trapdoors
- Hash functions and authentication codes
- Digital signatures, one-time signatures and random oracles.
- Identification protocols, Σ protocols.
- Security concepts such as unforgeable signatures and CPA- and CCA-secure encryption schemes.

5	**Learning outcomes and competences:** Upon completion of the module, students will be able to: • understand, explain and apply concepts and methods of modern cryptography. • select appropriate cryptographic methods according to the security requirements of an application, e.g. distinguish where encryption methods and where authentication methods are appropriate. • combine primitives of cryptography according to application requirements and prove the security of the combination. • define new security concepts and design cryptographic methods that satisfy those concepts. • understand and independently develop security proofs. • acquire latest research results in the field of cryptography by reading scientific papers.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Johannes Blömer

13	**Other Notes:** *Remarks of course Foundations of Cryptography:* **Implementation method** Basic concepts are presented in a lecture. In addition, theoretical concepts are deepened in tutorials in small groups. Written exercises and reading groups will be used to practice the practical application of these concepts. **Learning Material, Literature** • Oded Gorldreich, Foundations of Cryptography I,II, • Jonathan Katz, Yehuda Lindell, Introduction to Modern Cryptogtraphy • Slides from the lectures • Lecture notes

Human Factors in Security and Privacy			
Human Factors in Security and Privacy			
Module number: M.079.4092	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7059 Human Factors in Security and Privacy	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

4 **Contents:**

Contents of the course Human Factors in Security and Privacy:
Humans are important actors in security. A provable secure system is only useful if it can be actually used by users, and system designers need to account for human behavior if they wish to have both security and usability. In this class, we will examine factors of usability of security and privacy through a research-based, project-driven examination. We will cover core areas of security and privacy, as well as cover methods in human interaction (HCI) that can be used to measure the usability of security and privacy. Students are expected to complete problem sets on the topic and complete a research-based project. We will also practice academic conference reviewing, and model the academic publishing process while learning how to write and present academic research.
The course includes the following contents:

- How to write a scientific research paper?
- How to review a scientific research paper?
- How to conduct an independent scientific study in the field of Human Factors in Security and Privacy?
- Methodology: qualitative, quantitative and “mixed” methods.
- Introduction to research and scientific ethics
- Introduction to literature research
- Presenting scientific results at a conference
- How does scientific peer review work?

5 **Learning outcomes and competences:**

Students will be able to

- read and write peer reviews of scientific papers in the area of security, privacy, and usability.
- understand and apply research methods in human factors in usable security and privacy.
- develop relevant hypotheses and research questions in the space of usable security and privacy
- design and deploy a research study and analyze the results.
- describe, support, and effectively argue a result using the best practices of scientific writing.
- understand ethical issues related to human factors research in security and privacy.
- understand the major topics and themes of usable security and privacy.
- present research results in class.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Yasemin Acar

13	**Other Notes:** *Remarks of course Human Factors in Security and Privacy:* **Implementation Method** • The contents are presented and elaborated in the lecture. In the accompanying tutorial, the lecture topics are deepened and discussed both in plenary and in small groups. In addition, a scientific conference with peer review will be simulated, in which students will review and discuss research papers during the semester and present them in short talks. **Learning Material, Literature** • Current freely available research papers will be provided in the course. • Redmiles, Elissa M., Yasemin Acar, Sascha Fahl, and Michelle L. Mazurek. A summary of survey methodology best practices for security and privacy researchers. 2017. https://drum.lib.umd.edu/bitstream/handle/1903/19227/CS-TR-5055.pdf • Additional literature will be announced in the course.

Introduction to Quantum Computation			
Introduction to Quantum Computation			
Module number: M.079.4059	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7044 Introduction to Quantum Computation	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Introduction to Quantum Computation:
Recommended Proficiencies
Linear Algebra, algorithms

4 **Contents:**

Contents of the course Introduction to Quantum Computation:
This lecture introduces the fundamental concepts of quantum computation and information from a computer science perspective. This includes an introduction to quantum mechanics, quantum entanglement, quantum algorithms, quantum error correction, and quantum information theory.

- Quantum mechanics
- Quantum entanglement
- Quantum algorithms
- Quantum error correction
- Quantum information

5 **Learning outcomes and competences:**

Students are able to:

- Describe and apply the postulates of quantum mechanics
- Understand the use of entanglement as a resource
- Design and analyze fundamental quantum algorithms
- Apply the theory of error-correcting codes
- Understand and apply basic quantum information theory concepts such as entropy

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Sevag Gharibian

13 **Other Notes:**

Remarks of course Introduction to Quantum Computation:
Implementation method
Slides and blackboard writing. All important concepts and techniques are further deepened with examples in exercises.
Learning Material, Literature

- Michael A. Nielsen, Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press
- Lecture slides, exercises

Machine Learning for Biometrics			
Machine Learning for Biometrics			
Module number: M.079.4088	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7024 Machine Learning for Biometrics	L2 Ex3	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

4 **Contents:**

Contents of the course Machine Learning for Biometrics:
Biometric verification is defined as the automated recognition of individuals based on their behavioral or biological characteristics. The course will give an overview of modern biometric systems and specifically address their functionality and challenges. For this purpose, various approaches of machine learning will be introduced, which aim at enabling reliable biometric recognition (e.g. by means of face recognition). At the same time, biometric applications place very specific requirements on the underlying algorithms. The course will specifically address these requirements and how they can be met algorithmically and in the algorithmic learning process. This includes the topics of privacy, fairness, explainability, uncertainties, efficiency, attacks and their automated detection.
The course includes the following content:

- Biometric systems, operation modes, and evaluation
- Recap on traditional and deep learning
- Face, Iris, and fingerprint recognition
- Soft-biometrics and privacy
- Fairness and bias in biometric systems
- Explainability and confidence in biometric systems
- Biometric sample quality
- Efficient biometric systems
- Presentation attacks and detection
- Multi-biometric fusion
- Biometric indexing

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Students will be able to
• independently evaluate biometric systems,
• train biometric recognition models for different modalities,
• automatically detect biometric attacks and make systems robust against such attacks,
• explain various challenges of biometric systems and name solution strategies to counter them,
• name and explain open research questions in biometrics.</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
<table>
<tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr>
<tr><td>a)</td><td>Written or oral examination or report</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr>
</table></td></tr>
<tr><td>7</td><td>Study Achievement:
none</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
none</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr.-Ing. Philipp Terhörst</td></tr>
</table>

13	**Other Notes:** *Remarks of course Machine Learning for Biometrics:* **Implementation Method** First, students are given an overview of biometrics and its applications and basic functionalities. Then, required concepts of machine learning are introduced in a compact way. These will be applied and developed in context when dealing with specific biometric requirements. Parallel to the lecture, the theoretical concepts are practiced in the exercises using facial data. This is done in the form of short hand-written and implementation tasks. **Learning Material, Literature** • Anil K. Jain, Patrick Flynn, and Arun A. Ross. 2010. Handbook of Biometrics (1st. ed.). Springer Publishing Company, Incorporated. • Further literature will be announced in the lecture.

Post-Quantum Cryptography			
Post-Quantum Cryptography			
Module number: M.079.4089	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7015 Post-Quantum Cryptography	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Post-Quantum Cryptography:
Recommended Proficiencies
Basics of cryptography and complexity theory

4 **Contents:**

Contents of the course Post-Quantum Cryptography:
IT security is largely based on modern cryptographic methods. These include many methods of so-called public-key cryptography such as the RSA and Elgamal encryption methods, the RSA signature method, and the various variants of the Digital Signature Algorithm (DSA). In 1994, Peter Shor presented an efficient algorithm for computing prime factorization of integers and for computing discrete logarithms in finite groups. Thus, all the aforementioned methods of public-key cryptography are insecure if quantum computers of sufficient size and complexity can be realized. It is therefore important to develop alternatives to classical public-key methods that, at least according to current research, cannot be broken by quantum computers. Important candidates (and some close to standardization) for such post-quantum secure methods rely on techniques of error-correcting codes and the geometry of numbers. In this lecture, we will present and discuss important candidates for post-quantum secure methods. The course includes the following contents:

- introduction to codes, lattices and discretised Gaussian distributions
- lattice and code based enryption
- lattice based signatures
- lattices and zero-knowledge proofs
- lattice based group signatures

5 **Learning outcomes and competences:**

Students will be able to

- understand and explain the difference between classical and post-quantum security.
- explain the importance of post-quantum cryptography for selected applications.
- explain and apply concepts from the field of geometry of numbers and error-correcting codes.
- explain important constructions from post-quantum cryptography and prove their security.
- explain security assumptions from post-quantum cryptography and apply them to new post-quantum primitives.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Johannes Blömer

13 **Other Notes:**

Remarks of course Post-Quantum Cryptography:
Implementation Method
Basic concepts are presented in a lecture. In addition, theoretical concepts are deepened in tutorials in small groups as well as in written exercises.
Learning Material, Literature
References to current learning materials will be given in the lectures.

<table>
<tr><th colspan="4">Privacy and Technology</th></tr>
<tr><td colspan="4">Privacy and Technology</td></tr>
<tr><td>Module number:
M.079.4087</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
winter term</td></tr>
<tr><td>Language:
en</td><td>Semester number:
1-3</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
P</td></tr>
</table>

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7045 Privacy and Technology	L2 Ex3	75	105	CE	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

4 **Contents:**

Contents of the course Privacy and Technology:
This course provides students with a basic understanding of privacy risks and principles, the most common technologies for addressing them and the human factors that shape their design. The course will analyze the adversary models and evaluation metrics underlying the design of privacy-enhancing technologies. Moreover a quick overview of usable security as well as identity management and dedicated case studies will be given. For that, a superficial knowledge of HCI basics is desirable. By reviewing relevant papers and giving presentations, the students will get familiar with the latest research in the field and gain knowledge about how to work scientifically.
The course includes the following contents:

- Privacy metrics and adversary models
- Anonymous communications
- Data-perturbative privacy-enhancing technologies
- Anonymization algorithms for databases
- Homomorphic encryption and zero knowledge proofs
- Selective disclosure for identity management
- Usable privacy
- Applying privacy principles and case studies

5 **Learning outcomes and competences:**

The students

- are able to reason critically about privacy,
- gain knowledge in the evaluation of privacy risks,
- understand the design aspects of privacy-enhancing technologies,
- get familiar with the latest research in the field and
- analyze and discuss the space of solutions to a given privacy problem

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Patricia Arias Cabarcos

13 **Other Notes:**

Remarks of course Privacy and Technology:

Implementation Method

The contents are taught through a presentation in the form of a lecture. In addition, they are deepened in presence exercises in small groups, as well as through individual presentations. Through practical exercise, methods are implemented and applied.

Learning Material, Literature

- Lecture slides, scientific literature and specific readings will be provided during the course.

Quantum Complexity Theory

Quantum Complexity Theory

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4063	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7046 Quantum Complexity Theory	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Quantum Complexity Theory:
Recommended Proficiencies
Linear Algebra, Quantum Computing

4 **Contents:**

Contents of the course Quantum Complexity Theory:
This lecture provides a brief review of introductory quantum computation, and subsequently moves into quantum complexity theory. Beginning to advanced topics will be covered, including quantum analogues of P and NP (denoted BQP, QCMA, and QMA), quantum satisfiability problems, quantum interactive proofs, and tensor networks. Along the way, semidefinite programming will be introduced as an important tool.

- Complexity classes BQP, QCMA, QMA
- Quantum algorithms for linear system solving
- Quantum Satisfiability Problems
- Quantum Interactive Proofs
- Semidefinite Programming

5 **Learning outcomes and competences:**

Students will be able to

- Distinguish language classes from promise classes
- Define fundamental quantum complexity classes, such as BQP and QMA
- Prove BQP-hardness results via polynomial-time reductions
- Prove QMA-hardness results via polynomial-time reductions
- Apply semidefinite programming to analyze quantum interactive proofs

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Sevag Gharibian

13 **Other Notes:**

Remarks of course Quantum Complexity Theory:
Implementation method
Slides and blackboard writing. All important concepts and techniques are further deepened with examples in exercises.
Learning Material, Literature

- Michael A. Nielsen, Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press
- S. Gharibian, Y. Huang, Z. Landau, S. W. Shin, Quantum Hamiltonian Complexity, Foundations and Trends in Theoretical Computer Science
- Lecture slides, assignments

Real World Crypto Engineering

Real World Crypto Engineering

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4067	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7047 Real World Crypto Engineering	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Real World Crypto Engineering:
Recommended Proficiencies
Knowledge in programming, IT security and basic knowledge in cryptography

4 **Contents:**

Contents of the course Real World Crypto Engineering:
Strong cryptography is not always sufficient to protect primary security goals. Even if strong cryptographic algorithms are used, a lot can go wrong when they are implemented. This lecture will dive into the most important protocols and cryptographic protection mechanisms (e.g., TLS, SSH, WPA) and show their basic concepts. Then, we will present prominent attacks that ultimately break the desired security goals. Based on many cases, we will learn what is essential when designing and implementing cryptographic applications.
The course includes the following contents:

- Brief introduction to cryptography
- TLS (Transport Layer Security)
- Attacks on TLS (e.g., ROBOT, DROWN, or Invalid Curve)
- Evaluation of implementations with systematic methods (e.g., with fuzzing or state learning)
- SSH (Secure Shell)
- Signal
- Cryptocurrencies

5	**Learning outcomes and competences:** Students will be able to • Understand concepts behind major cryptographic protocols • Understand and prevent common attacks on cryptographic protocols • Conduct analyses of cryptographic implementations using systematic methods and standard tools • Identify and assess implementation errors and security issues in cryptographic protocols
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr.-Ing. Juraj Somorovsky

13	**Other Notes:** *Remarks of course Real World Crypto Engineering:* **Implementation method:** The topics are conveyed through lecture presentations. They are further deepened through individual practical tasks. **Learning Material, Literature:** • Lecture slides and exercise sheets • Scientific literature • Additional literature will be announced in the course.

Usable Security and Privacy			
Usable Security and Privacy			
Module number: M.079.4086	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7048 Usable Security and Privacy	L2 Ex3	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

4 **Contents:**

Contents of the course Usable Security and Privacy:
Human factors and usability issues have traditionally played a limited role in security research and secure systems development. Usability issues have been largely disregarded by security experts due to their failure to acknowledge their significance and their insufficient knowledge to tackle them. Today there is consensus on the importance of understanding users behavior and improving usability to achieve true security. This course provides practical and research-oriented knowledge about usable security and privacy. Students will gain practical experience through focused presence exercises and work in small teams to conduct a semester-wide research project with the goal of designing and pretesting a user study on human-centered security and privacy. For that, the course will present research methods and give an introduction into HCI and usability concepts. The course will also address foundational and state-of-the-art research topics in the area, such as privacy and transparency enhancing tools, usable authentication, and developer-centered security. By reviewing relevant papers and giving presentations, the students will get familiar with the latest research in the field and gain knowledge about how to work scientifically.
The course includes the following contents:

- Security and privacy concepts
- Foundations of cryptography
- Privacy and transparency enhacing tools
- HCI and usability research methods
- Ethics in technology
- Quantitative and qualitative data analysis
- Usable authentication
- Usable privacy
- Developer-centered security

5	**Learning outcomes and competences:** Students will • gain an appreciation for the importance of usable security and privacy • learn about the history of the field and main research areas and challenges • are able to apply methodologies to conduct user research in security and privacy • get familiar with the latest research in the field
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Patricia Arias Cabarcos

13	**Other Notes:** *Remarks of course Usable Security and Privacy:* **Implementation method** Basic concepts are presented in a lecture style format. By engaging in presence exercises and conducting a research project in small groups focused on a user-study for usable security and privacy research throughout the semester, students can acquire more profound theoretical and practical knowledge. **Learning Material, Literature** • Lazar, J., Feng, J.H. and Hochheiser, H., 2017. Research methods in human-computer interaction. Morgan Kaufmann. • Redmiles, E.M., Acar, Y., Fahl, S. and Mazurek, M.L., 2017. A summary of survey methodology best practices for security and privacy researchers. • Slides and scientific literature references will be given during the course.

Web Security			
Web Security			
Module number: M.079.4073	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7049 Web Security	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Web Security:
Recommended Proficiencies
Knowledge in programming, IT security and basic knowledge in cryptography

4 **Contents:**

Contents of the course Web Security:
Modern web applications and web services usually consist of multiple layers. They are based on different (often complex) technologies that are constantly being developed. Their complexity is often the reason for new types of attacks that can be observed on the web every day.
In this lecture, we will focus on the most important technologies and learn what you have to consider while securing your web applications. We will introduce prominent and widespread attacks and show how to prevent them. These range from typical attacks from the OWASP Top 10 list, such as XSS or SQL Injection, to attacks on web services and Single Sign-On standards (e.g., on SAML and OpenID Connect). Based on many cases, we will learn what is important in the design and implementation of secure web applications.
The course includes the following contents:

- Introduction to web technologies
- Web Attacks
  - Cross-Site Scripting (XSS)
  - Cross-Site Request Forgery (CSRF)
  - Clickjacking
  - SQL injection
- XML and SAML
  - Attacks on XML parsers
  - Attacks on XML Signature
- JSON and OpenID Connect (OIDC)
  - Attacks on OIDC

5 **Learning outcomes and competences:**

Students will be able to

- Understand security concepts behind web applications
- Understand and prevent common attacks on web applications
- Carry out practical analyses of web applications with common tools
- Identify and assess implementation errors and security problems in web applications

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr.-Ing. Juraj Somorovsky
13	**Other Notes:** *Remarks of course Web Security:* **Implementation method:** The topics are conveyed through lecture presentations. They are further deepened through individual practical tasks. **Learning Material, Literature:** • Lecture slides and exercise sheets • Scientific literature • Additional literature will be announced in the course.

4.11 Computer Science Focus Area Software Engineering

Concepts of Computer Science

Concepts of Computer Science

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4203	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7056 Concepts of Computer Science	L2 Ex3	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Concepts of Computer Science:
Recommended Proficiencies

- Good general education
- Ability to read and analyze longer and complex texts from computer science as well as the humanities

4 **Contents:**

Contents of the course Concepts of Computer Science:
The course examines the interplay of digital artifacts and cognitive performance. For this purpose, the epistemological and methodological foundations will be developed that allow the diverse relationships between computer science systems and their application to be addressed in such a way that the computer science-specific consequences become apparent. In the class, these concepts will be systematically analyzed and evaluated historically, technically, and with respect to their potentials.
The lecture discusses the relevant theoretical and conceptual foundations of computer science. Special attention will be paid to differentiate between technical concepts and the sphere of usage. Against this background, theories of interactive systems will be explored in order to examine which role technical artifacts play with respect to processes of the mind. When developing computer systems, relevant data and processes need to be anticipated to a certain degree and modeled as formal systems. This raises issues like the question under which conditions such a formal description can be made in an adequate way and with which consequences regarding the reliability and responsible use of computer systems.
The course includes the following contents:

- Basic concepts of computer science
- Historical background of developments in computer science
- Digital media and mental processes
- Theories of digital media and interactive systems
- Paradigms of support and replacement of mental processes
- Modeling and formalization of data and processes
- Trustworthiness of systems

5 **Learning outcomes and competences:**

Students will be able to

- examine the characteristics of computer systems in a theory-based manner,
- explain cognitive-psychological, sociological and system-theoretical basics of computer science
- differentiate technical and non-technical issues and relate them adequately to each other,
- evaluate and compare current technological developments
- assess innovation potentials in the field of digital technologies,
- weigh risks and potentials for successful use of information technology systems.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

<table>
<tr><td>7</td><td>Study Achievement:
<table>
<tr><th>zu</th><th>Type of achievement</th><th>Duration or Scope</th><th>SL / QT</th></tr>
<tr><td>a)</td><td>Assignments, course paper or progress reports</td><td></td><td>CA</td></tr>
</table>
</td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
Passing of course achievement</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4</td></tr>
<tr><td>12</td><td>Module coordinator:
Dr. Harald Selke</td></tr>
<tr><td>13</td><td>Other Notes:
<i>Remarks of course Concepts of Computer Science:</i>
Implementation method
The lecture follows a flipped classroom concept in which students learn about topics based on their reading of scientific literature as well as individual research. They will then present these topics in short presentations in the tutorials in the style of a mini-seminar. Building on this, the lecture then conveys connections between the literature covered in the tutorials and adds further facets.
Learning Material, Literature

Lecture slides
Wardrip-Fruin, N.; Montfort, N. (eds.): The New Media Reader. Cambridge, Ma.: MIT Press, 2003.
Additional scientific literature will be announced in the lectures.

</td></tr>
</table>

Data-Driven Engineering

Data-Driven Engineering

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4204	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.705b Data-Driven Engineering	L2 Ex3	75	105	C	60/30

2 **Options within the module:**

none

3 **Admission requirements:**

none

4 **Contents:**

Contents of the course Data-Driven Engineering:
The goal of the lecture is to provide a comprehensive overview of the potentials and use cases in data-driven engineering. Important fundamentals and concepts from the fields of engineering and artificial intelligence are introduced and explained using meaningful practical examples. The acquired knowledge is deepened and implemented in exercises. As part of a group project, participants will develop their own functional engineering assistant.
Data is the oil of the 21st century. Data is also becoming increasingly important in product development. Both field data and development data can be processed using modern data analysis methods and AI processes to increase the efficiency and effectiveness of product development. The lecture provides an overview of the challenges and possible solutions of Data-driven Engineering. Theoretical principles and concepts are introduced and exemplary applications from practice are presented. The process is considered from data acquisition to possibilities for data evaluation and the development of innovative assistance systems. The acquired knowledge is deepened and implemented in the exercises.
Contents of the course are:

- Motivation and definition of terms
- Potentials of data-driven engineering
- Engineering IT and data management along the product life cycle
- Fundamentals of data analytics and AI (in particular generative AI)
- Data structures and formats in product development
- Application examples and assistance systems (co-pilots) along the product life cycle (from requirements engineering to production planning)
- Methods for planning and implementing Data-driven Engineering use cases
- Technical development of assistance systems (co-pilots) in Data-driven Engineering

5 **Learning outcomes and competences:**

Students will be able to

- recognize and evaluate the potential of Data-driven Engineering
- evaluate prerequisites for the application of Data-driven product development concepts
- analyze and design Engineering IT infrastructures
- plan and implement use cases for Data-driven product development
- design assistance systems (co-pilots) for Data-driven use cases

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	90-120 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

none

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4, Master’s Program Electrical Systems Engineering (ESEMA v2), Master’s Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr.-Ing. Roman Dumitrescu

13 **Other Notes:**

Remarks of course Data-Driven Engineering:
Implementation Method
The course consists of three components: In the lecture, basic concepts of data-driven engineering are introduced using slides and underlined with practical examples. In the accompanying exercise, the concepts are applied by the students. The project allows students to apply what they have learned in group work.
Learning Material, Literature

- Literature will be announced in the course.

Data-Driven Innovation			
Data-Driven Innovation			
Module number: M.079.4076	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7052 Data-Driven Innovation	L2 Ex3	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

4	**Contents:** *Contents of the course Data-Driven Innovation:* Innovations arise when companies successfully launch new or improved products and services on the market. Innovations are the prerequisite for prosperity, economic growth and competitive advantages. The increasing digitalization of all aspects of our lives has given rise to numerous new approaches to innovation and how it is created. The Data-Driven Innovation lecture provides a basic overview of this: The basics of innovation and data management are discussed, new digitized market services and business models are discussed and the impact on the innovation process is examined and analyzed. Building on this, the course deals with how organizations can implement data-driven innovations. The module includes the following content: • Innovation and Data – Fundamentals of Innovation Management – Fundamentals of Data in Organizations • Data-Driven Offerings – Smart Products – Smart Services – Digital Platforms – Data Spaces & Digital Business Models • Innovation Processes – Innovation Management Methods and Tools – Data-infused Innovation Processes • Organizing the data-driven Transformation – Digital Transformation – Using data for Sustainability
5	**Learning outcomes and competences:** The students • become familiar with the basics of innovation and data management as well as key concepts and approaches • understand the influence of digitalization on the market performance of manufacturing companies in particular • be able to understand and reflect on innovation processes in practice • understand how the transformation to a data-driven company can take place • be able to apply various approaches to analyze problems and find solutions. • be able to systematically find, conceptualize, test and develop ideas towards a market approach.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

none

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4, Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Dr. Christian Koldewey, Prof. Dr.-Ing. Roman Dumitrescu

13 **Other Notes:**

Remarks of course Data-Driven Innovation:
Implementation method
The module consists of two parts 1. lecture with slides: basics and concepts are explained in the lecture and illustrated with examples. 2. exercises (tutorial): In the exercises, knowledge is transferred and the concepts are applied. The exercises have to be prepared by the students themselves.
Learning Material, Literature

- Gausemeier, Jürgen & Dumitrescu, Roman & Echterfeld, Julian & Pfänder, Tomas & Steffen, Daniel & Thielemann, Frank. (2018). Innovationen für die Märkte von morgen: Strategische Planung von Produkten, Dienstleistungen und Geschäftsmodellen. 10.3139/9783446429727. (https://www.hanser-fachbuch.de/fachbuch/artikel/9783446428249#content–desc)
- Beverungen, Daniel & Dumitrescu, Roman & Kühn, Arno & Plass, Christoph. (2024). Digitale Plattformen im industriellen Mittelstand Strategien, Methoden, Umsetzungsbeispiele.
- https://ki-marktplatz.com/wp-content/uploads/2021/02/KI-MP_Whitepaper.pdf
- https://www.advanced-systems-engineering.de/#studie

Data Science for Software Engineering			
Data Science for Software Engineering			
Module number: M.079.4101	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** summer term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** WP

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	Data Science for Software Engineering	L2 Ex3	75	105	CE	30

2 **Options within the module:**

none

3 **Admission requirements:**

Prerequisites of course Data Science for Software Engineering:
Recommended Proficiencies
Good programming skills using Java and/or Python is helpful to make the assignments. Basic background on machine learning is helpful to understand some of the Data Science concepts.

4 **Contents:**

Contents of the course Data Science for Software Engineering:
Software engineers deal with software repositories in their daily work, such as when they develop source code in version control systems, or post issues in issue trackers, or communicate through emails in mailing lists, or discuss in forums and blogs. The big amount of data in software repositories, their continuous evolution, complexity and heterogeneity present a challenge for software engineers. In the past years, researchers proposed approaches that use techniques from the data science to support software engineers. This course will explain the application of data science techniques on software repositories to achieve common software engineering tasks. The course includes the following topics:

- Types and structure of software repositories.
- Clustering of source code.
- Natural language processing pipeline.
- Topic modeling.
- Word embedding.
- Information retrieval.
- Supervised machine learning.
- Statistical analysis.

Concepts are discussed in the lectures and applied using a set of group assignments to analyze opensource systems, ans achieve certain software architecture and maintenance tasks.

5 **Learning outcomes and competences:**

Students will be able to

- Clarify and discuss types and structure of software repositories.
- Clarify and discuss main concepts of data science techniques, and their application on sotware repositories.
- Apply data science techniques on large-scale software repositories.
- Derive useful implications from the analysis results.
- Summarize and report analysis results in a scientific format.
- Work in teams.
- Write scientific reports
- Present research results

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination	90-120 min or 30-45 min	100%

7 **Study Achievement:**

zu	**Type of achievement**	**Duration or Scope**	**SL / QT**
a)	Assignments and short presentations		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v3, Masterstudiengang Informatik v4

12 **Module coordinator:**

Dr. Mohamed Aboubakr Mohamed Soliman

13	**Other Notes:** *Remarks of course Data Science for Software Engineering:* **Implementation Method** The course focus on the application of data science methods in software engineering more than the mathematical background of data science methods. The main concepts of methods are conveyed through a presentation as part of a lecture and the application of methods is further investigated through group assignments and presentations. **Learning Material, Literature** Beside the slides, further learning materials from prominent publications in the software engineering literature will be provided for each topic.

Data Science in Industrial Applications			
Data Science in Industrial Applications			
Module number: M.079.4075	**Workload (h):** 180	**Credits:** 6	**Regular Cycle:** winter term
Language: en	**Semester number:** 1-3	**Duration (in sem.):** 1	**Module status (P=C/WP=CE)** P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7053 Data Science in Industrial Aplications	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

4 **Contents:**

Contents of the course Data Science in Industrial Applications:
The course “Data Science in Industrial Applications” deals with the methods and techniques of data analysis in an industrial context. Students learn basic concepts of data analysis and how to apply them in practice.
The increasing networking of machines, sensors and IT systems in the context of Industry 4.0 has led to a rapid increase in the amount of available data. The analysis of data offers enormous potential for the automation of cognitive tasks, the optimization of processes and the further creation of value from data. The lecture will provide an overview of the challenges and solution approaches for the industrial application of Data Science. This includes the integration of industrial data sources from the field, the IT landscape in manufacturing companies and the setup of (Big Data) infrastructure, typical algorithms in the area of time series processing, optimization or image processing as well as the embedding in business processes. Theoretical and methodological basics, concepts and tools are introduced during the lecture and applied in small groups based on a case study as well as deepened in home exercises. The theoretical concepts for the planning, introduction and implementation of Industrial Data Science in theory are supplemented by practical real-life examples.

5	**Learning outcomes and competences:** Students - understand the challenges of applying Data Science in industrial applications, - have an overview of typical application examples, - are able to apply methods of signal processing, machine learning, and statistics to industrial problems, - are able to plan the implementation of data acquisition, data architecture, and integration into business processes, - are able to develop solutions on their own as well as in cooperation, - are proficient in basic project management skills.
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)
7	**Study Achievement:**
8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr.-Ing. Roman Dumitrescu

Assessments (6):

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

Study Achievement (7):

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

13 **Other Notes:**

Remarks of course Data Science in Industrial Applications:

Implementation Method

The course includes lectures (slide-based), exercises (interactive), and project work. In the lectures, the theoretical basics of data analysis in an industrial context are taught. In the exercises, students have the opportunity to apply what they have learned by means of practical tasks. The project work offers the students the opportunity to apply the learned knowledge in a larger context. In the exercise, knowledge transfer and application of the concepts take place in a case study in the form of workshops and implementation of an industrial analytics application in independent group work.

Learning Material, Literature

A more detailed list of the lecture materials and references will be given in the first course. A good first insight into the subject area is given by:

- Wiendahl, Hans-Peter; Wiendahl, Hans-Hermann (2019): Betriebsorganisation für Ingenieure. 9., vollständig überarbeitete Auflage. München: Hanser (Hanser eLibrary).
- Zahn, Erich; Schmid, Uwe (1996): Grundlagen und operatives Produktionsmanagement. Mit 42 Tabellen. Stuttgart: Lucius & Lucius (Grundwissen der Ökonomik Betriebswirtschaftslehre, 1).
- Günther Schuh; Achim Kampker: Strategie und Management produzierender Unternehmen: Handbuch Produktion und Management 1 (VDI-Buch) (German Edition).
- Schuh, Günther; Riesener, Michael (2018): Produktkomplexität managen. Strategien - Methoden - Tools. 3., vollständig überarbeitete Auflage. München: Hanser (Hanser eLibrary). Online verfügbar unter http://www.hanser-elibrary.com/doi/book/10.3139/9783446453340.
- Schuh, Günther; Schmidt, Carsten (2014): Produktionsmanagement. DOI: 10.1007/978-3-642-54288-6.
- Bishop, Christopher M. (2006): Pattern recognition and machine learning. New York: Springer (Information science and statistics).
- Cao, Longbing (2018): Data Science. In: ACM Comput. Surv. 50 (3), S. 1–42. DOI: 10.1145/3076253.
- Geron, Aurelien (2019): Hands-On Machine Learning with Scikit-Learn and TensorFlow: O'Reilly Media.
- Goodfellow, Ian; Bengio, Yoshua; Courville, Aaron (2016): Deep Learning. MIT Press.
- James, Gareth; Witten, Daniela; Hastie, Trevor; Tibshirani, Robert (2013): An Introduction to Statistical Learning. New York, NY: Springer New York (103).
- Mitchell, Tom M. (1997): Machine Learning. New York: McGraw-Hill (McGraw-Hill series in computer science).
- Runkler, Thomas A. (2016): Data Analytics. Wiesbaden: Springer Fachmedien Wiesbaden.
- Russell, Stuart (2009): Artificial Intelligence: A Modern Approach. 3rd Edition. Pearson.
- Schutt, Rachel; O'Neil, Cathy (2013): Doing data science. Straight talk from the frontline. 1. ed. Beijing: O'Reilly.

Designing code analyses for large-scale software systems 1

Designing code analyses for large-scale software systems 1

Module number:	Workload (h):	Credits:	Regular Cycle:
M.079.4070	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7041 Designing code analyses for large-scale software systems 1	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Designing code analyses for large-scale software systems 1:
Recommended Proficiencies
A mature understanding of the Java programming languages and object-oriented programming will be helpful.

4 **Contents:**

Contents of the course Designing code analyses for large-scale software systems 1:
Static code analysis is frequently used to find programming mistakes automatically, by searching for suspicious anti-patterns in a program's code. This course will explain how to design static code analysis that are inter-procedural, i.e., consider the whole program, across procedure boundaries. Designing such analyses is challenging, as they need to handle millions of program statements efficiently and precisely. Example applications are drawn from the area of IT security.
This course is part of a combination DECA 1/2. In DECA 2 we will be covering current approaches directly our of research. We strongly recommend attending DECA 1 before DECA 2.
Topics covered include:

- Type systems and flow-insensitive, contraint-based analysis
- Lattices and fixed points
- Intra-procedural flow-sensitive static code analysis
- Interval analysis, widening and narrowing
- Call-graph construction
- Pointer Analysis
- Inter-procedural program analysis
- Call-strings approach to context-sensitive analysis
- Functional approach to context-sensitive analysis
- Value-based termination, VASCO
- Distributive analyses using IFDS
- Sensible arrangements of Flow Functions
- Distributive analyses using IDE

Throughout, we will discuss applications to software security.

5 **Learning outcomes and competences:**

Upon completion of the module, students will be able to

- name and distinguish the most important concepts and algorithms in the field of static program analysis
- explain the effects of various alternative design decisions when designing a static program analysis
- implement and apply simple static program analyses themselves and illustrate their function
- contrast and compare data structures and algorithms for static program analysis
- evaluate and justify the applicability of certain analysis procedures to specific application contexts, and
- develop tools for static program analysis by composing several analysis methods.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8 **Prerequisites for participation in examinations:**

Passing of course achievement

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4

12 **Module coordinator:**

Prof. Dr. Eric Bodden

13 **Other Notes:**

Remarks of course Designing code analyses for large-scale software systems 1:
Implementation method
Lectures and group exercises as well as practical programming labs using worldwide leading frameworks for static code analysis
Learning Material, Literature

- Thomas Reps, Susan Horwitz, and Mooly Sagiv. 1995. Precise interprocedural dataflow analysis via graph reachability. POPL ’95
- Shmuel Sagiv, Thomas W. Reps, and Susan Horwitz. 1995. Precise Interprocedural Dataflow Analysis with Applications to Constant Propagation. TAPSOFT ’95
- Akash Lal, Thomas Reps, and Gogul Balakrishnan. 2005. Extended weighted pushdown systems. CAV 2005
- Nomair A. Naeem, Ondrej Lhoták, and Jonathan Rodriguez. 2010. Practical extensions to the IFDS algorithm. CC 2010
- Yannis Smaragdakis, Martin Bravenboer, and Ondrej Lhoták. 2011. Pick your contexts well: understanding object-sensitivity. POPL 2011
- Eric Bodden. 2012. Inter-procedural data-flow analysis with IFDS/IDE and Soot. SOAP 2012
- Rohan Padhye, Uday P. Khedker. Interprocedural Data Flow Analysis in Soot using Value Contexts. SOAP 2013

<table>
<tr><th colspan="4">Designing code analyses for large-scale software systems 2</th></tr>
<tr><td colspan="4">Designing code analyses for large-scale software systems 2</td></tr>
<tr><td>Module number:
M.079.4071</td><td>Workload (h):
180</td><td>Credits:
6</td><td>Regular Cycle:
summer term</td></tr>
<tr><td>Language:
en</td><td>Semester number:
2-3</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
P</td></tr>
</table>

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7042 Designing code analyses for large-scale software systems 2	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Designing code analyses for large-scale software systems 2:
Recommended Proficiencies
We strongly recommend that attendees have completed DECA 1 beforehand. A mature understanding of the Java and/or C++ programming languages and object-oriented programming will be helpful.

4 **Contents:**

Contents of the course Designing code analyses for large-scale software systems 2:
Static code analysis has the goal of finding programming mistakes automatically, by searching for suspicious anti-patterns in a program's code. This course will explain how to design static code analysis that are inter-procedural, i.e., consider the whole program, across procedure boundaries. Designing such analyses is challenging, as they need to handle millions of program statements efficiently and precisely. Example applications are drawn from the area of IT security.
This course builds on the DECA 1 course. In DECA 2, we discuss novel concepts directly from research, for example so-called demand-driven analyses, which are characterized by a more precise and at the same time more efficient analysis, but also pushdown systems, which provide a allow elegant modeling and at the same time fast execution of program analyses. Last but not least, we explain current solutions to practical problems in static analysis, such as the use of reflection and native code.
Topics covered include:

- Program analysis of software product lines
- Modeling call stacks and field accesses with Pushdown Systems
- Modeling auxiliary analysis information with Weighted Pushdown Systems
- Efficiency and precision gains through Demand-driven Program Analysis
- Synchronized Pushdown Systems in the Boomerang framework
- Applied Android code analysis with FlowDroid
- Dealing with Reflection through TamiFlex
- Hybrid static and dynamic analysis with Harvester
- Learning source, sink and sanitizer definitions with SWAN and SWAN Assist
- Explainable static analysis

5 **Learning outcomes and competences:**

Upon completion of the module, students will be able to

- name and explain the most important challenges in inter-procedural static program analysis
- name and distinguish current methods in the field of inter-procedural static program analysis
- explain the implications of various alternative design decisions in the design of an inter-procedural static program analysis.
- contrast and compare data structures and algorithms for inter-procedural static program analysis and
- evaluate and justify the applicability of current analysis techniques in a broad range of application contexts.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	120-180 min or 30-45 min or 30 min	100%

7	**Study Achievement:** <table><tr><th>zu</th><th>Type of achievement</th><th>Duration or Scope</th><th>SL / QT</th></tr><tr><td>a)</td><td>Assignments, course paper or progress reports</td><td></td><td>CA</td></tr></table>
8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Prof. Dr. Eric Bodden
13	**Other Notes:** *Remarks of course Designing code analyses for large-scale software systems 2:* **Implementation method** Lectures and group exercises as well as programming exercises using widely used real-world static analysis frameworks (e.g. Soot, Phasar, FlowDroid) **Learning Material, Literature** • Context-, Flow-, and Field-sensitive Data-flow Analysis Using Synchronized Pushdown Systems (Johannes Späth, Karim Ali, Eric Bodden), In Proceedings of the ACM SIGPLAN Symposium on Principles of Programming Languages, pages 48:1–48:29, 3(POPL), 2019. • FlowDroid: Precise Context, Flow, Field, Object-sensitive and Lifecycle-aware Taint Analysis for Android Apps (Steven Arzt, Siegfried Rasthofer, Christian Fritz, Eric Bodden, Alexandre Bartel, Jacques Klein, Yves Le Traon, Damien Octeau, Patrick McDaniel), In Proceedings of the 35th ACM SIGPLAN Conference on Programming Language Design and Implementation, pages 259–269, PLDI '14, ACM, 2014. • Codebase-Adaptive Detection of Security-Relevant Methods (Goran Piskachev, Lisa Nguyen Quang Do, Eric Bodden), In ACM SIGSOFT International Symposium on Software Testing and Analysis (ISSTA), 2019. • Taming Reflection: Aiding Static Analysis in the Presence of Reflection and Custom Class Loaders (Eric Bodden, Andreas Sewe, Jan Sinschek, Hela Oueslati, Mira Mezini), In ICSE '11: International Conference on Software Engineering, pages 241–250, ACM, 2011.

Human Factors in Security and Privacy

Human Factors in Security and Privacy

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4092	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	P

1 **Module structure:**

	Course	form of teachin	contact-time (h)	self-study (h)	status (C/CE)	group size (TN)
a)	2024.7059 Human Factors in Security and Privacy	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

4 **Contents:**

Contents of the course Human Factors in Security and Privacy:
Humans are important actors in security. A provable secure system is only useful if it can be actually used by users, and system designers need to account for human behavior if they wish to have both security and usability. In this class, we will examine factors of usability of security and privacy through a research-based, project-driven examination. We will cover core areas of security and privacy, as well as cover methods in human interaction (HCI) that can be used to measure the usability of security and privacy. Students are expected to complete problem sets on the topic and complete a research-based project. We will also practice academic conference reviewing, and model the academic publishing process while learning how to write and present academic research.
The course includes the following contents:

- How to write a scientific research paper?
- How to review a scientific research paper?
- How to conduct an independent scientific study in the field of Human Factors in Security and Privacy?
- Methodology: qualitative, quantitative and “mixed” methods.
- Introduction to research and scientific ethics
- Introduction to literature research
- Presenting scientific results at a conference
- How does scientific peer review work?

<table>
<tr><td>5</td><td>Learning outcomes and competences:
Students will be able to
read and write peer reviews of scientific papers in the area of security, privacy, and usability.
understand and apply research methods in human factors in usable security and privacy.
develop relevant hypotheses and research questions in the space of usable security and privacy
design and deploy a research study and analyze the results.
describe, support, and effectively argue a result using the best practices of scientific writing.
understand ethical issues related to human factors research in security and privacy.
understand the major topics and themes of usable security and privacy.
present research results in class.</td></tr>
<tr><td>6</td><td>Assessments:
☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)<table><tr><th>zu</th><th>Type of examination</th><th>Duration or scope</th><th>Weighting for the module grade</th></tr><tr><td>a)</td><td>Written or oral examination or report</td><td>120-180 min or 30-45 min or 30 min</td><td>100%</td></tr></table></td></tr>
<tr><td>7</td><td>Study Achievement:<table><tr><th>zu</th><th>Type of achievement</th><th>Duration or Scope</th><th>SL / QT</th></tr><tr><td>a)</td><td>Assignments, course paper or progress reports</td><td></td><td>CA</td></tr></table></td></tr>
<tr><td>8</td><td>Prerequisites for participation in examinations:
Passing of course achievement</td></tr>
<tr><td>9</td><td>Prerequisites for assigning credits:
The credit points are awarded after the module examination was passed.</td></tr>
<tr><td>10</td><td>Weighing for overall grade:
The module is weighted according to the number of credits (factor 1).</td></tr>
<tr><td>11</td><td>Reuse in degree courses or degree course versions :
Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4</td></tr>
<tr><td>12</td><td>Module coordinator:
Prof. Dr. Yasemin Acar</td></tr>
</table>

13 **Other Notes:**

Remarks of course Human Factors in Security and Privacy:
Implementation Method

- The contents are presented and elaborated in the lecture. In the accompanying tutorial, the lecture topics are deepened and discussed both in plenary and in small groups. In addition, a scientific conference with peer review will be simulated, in which students will review and discuss research papers during the semester and present them in short talks.

Learning Material, Literature

- Current freely available research papers will be provided in the course.
- Redmiles, Elissa M., Yasemin Acar, Sascha Fahl, and Michelle L. Mazurek. A summary of survey methodology best practices for security and privacy researchers. 2017. https://drum.lib.umd.edu/bitstream/handle/1903/19227/CS-TR-5055.pdf
- Additional literature will be announced in the course.

Model-Based Systems Engineering

Model-Based Systems Engineering

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4062	180	6	summer term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.7058 Model-Based Systems Engineering	L3 Ex2	75	105	C	70/35

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Model-Based Systems Engineering:
Recommended Proficiencies
Basics of Systems Engineerings

4 **Contents:**

Contents of the course Model-Based Systems Engineering:
Due to the technical change from mechatronic to intelligent technical systems (ITS), companies and development teams are facing many challenges. A key factor is the increase in complexity and networking of systems (products). Existing approaches in product development cannot cover this efficiently and effectively. Model-based Systems Engineering (MBSE) presents itself as a promising approach to solve these challenges. MBSE sees itself as a further development of systems engineering and builds on its foundations. Systems engineering, which is primarily based on documents, is extended by the introduction of models.
The course includes the following content:

- Intelligent Engineering Systems
- Model-based Systems Engineering 101
- Systems Modeling Fundamentals
- Languages and Methods - CONSENS, SysML
- Systems Architecting
- IT Tools for MBSE

5 **Learning outcomes and competences:**

The students

- acquire a solid understanding of Model-Based System Engineering
- know different methods, languages, and tools
- are able to apply the knowledge they have gained
- are able to work out solutions independently and communicate them to the lecturers.

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	**Type of examination**	**Duration or scope**	**Weighting for the module grade**
a)	Written or oral examination or report	90-120 min or 30-45 min or 30 min	100%

7 **Study Achievement:**

none

8 **Prerequisites for participation in examinations:**

none

9 **Prerequisites for assigning credits:**

The credit points are awarded after the module examination was passed.

10 **Weighing for overall grade:**

The module is weighted according to the number of credits (factor 1).

11 **Reuse in degree courses or degree course versions :**

Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4, Master's Program Electrical Systems Engineering (ESEMA v2), Master's Program Electrical Systems Engineering v3 (ESEMA v3)

12 **Module coordinator:**

Prof. Dr.-Ing. Roman Dumitrescu

13 **Other Notes:**

Remarks of course Model-Based Systems Engineering:
Implementation Method
The module consists of two parts

1. lecture with slides: basics and concepts are explained in the lecture and illustrated with examples.
2. exercises (tutorial): In the exercises, knowledge is transferred and the concepts are applied. The exercises have to be prepared by the students themselves.

Learning Material, Literature

- Gausemeier, J.; Dumitrescu, R.; Steffen, D.; Czaja, A.; Wiederkehr, O.; Tschirner, C.: Systems Engineering in industrial practice. Heinz Nixdorf Institute, University Paderborn, 2013, Under: https://www.hni.uni-paderborn.de/en/spe/systemsengineering/
- Dumitrescu, R.; Albers, A.; Riedel, O.; Stark, R.;Gausemeier, J. (Eds): Engineering in Germany – Status quo in Business and Science. Federal Ministry of Education and Research, 2021 Under: https://www.advanced-systems-engineering.de/#studie
- Additional literature will be announced in the course.

Software Architecture Design and Recovery

Software Architecture Design and Recovery

Module number:	**Workload (h):**	**Credits:**	**Regular Cycle:**
M.079.4094	180	6	winter term
Language:	**Semester number:**	**Duration (in sem.):**	**Module status (P=C/WP=CE)**
en	1-3	1	WP

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	2024.705a Software Architecture Design and Recovery	L2 Ex3	75	105	C	30

2 **Options within the module:**

none

3 **Admission requirements:**

none

Prerequisites of course Software Architecture Design and Recovery:
Recommended Proficiencies
A good understanding of Java and the principle of object-oriented programming is helpful.

4 **Contents:**

Contents of the course Software Architecture Design and Recovery:
Software architecture is concerned with the principal design decisions of a software system. These decisions have significant impact on the system's quality, such as maintainability, performance and security. This course will explain fundamental concepts of the software architecture field, as well as how to apply techniques to recover design decisions from existing software repositories. The course includes the following topics from software architecture field:

- Types of design decisions.
- Architectural components and recovery.
- Architectural solutions such as patterns, tactics and technologies.
- Architectural documentation.
- Software repositories.
- Architectural knowledge.
- Design processes.

Furthermore, the course discusses and applies common research methods:

- Grounded theory
- Case studies

5	**Learning outcomes and competences:** Students will be able to • clarify and discuss main concepts in the software architecture field, such as architectural solutions, components, and design processes • analyze large-scale software systems for architectural design decisions • execute design processes to make design decisions • apply common research methods on software architecture problems • summarize and report research results in a scientific format • work in teams • present their results to the audience
6	**Assessments:** ☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a)	Written or oral examination or report	90-120 min or 30-45 min or 30 min	100%

7	**Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Assignments, course paper or progress reports		CA

8	**Prerequisites for participation in examinations:** Passing of course achievement
9	**Prerequisites for assigning credits:** The credit points are awarded after the module examination was passed.
10	**Weighing for overall grade:** The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4), Masterstudiengang Informatik v4
12	**Module coordinator:** Dr. Mohamed Aboubakr Mohamed Soliman

13 **Other Notes:**

Remarks of course Software Architecture Design and Recovery:
Implementation Method
Lectures and group assignments on large open-source software systems, as well as presentations. Concepts are discussed in the lectures and applied using a set of group assignments on real open-source software systems.
Learning Material, Literature

- Bass, L., Clements, P., Kazman, R. (2012). Software Architecture in Practice. 3rd Edition, Addison-Wesley Professional.
- Kruchten P, Lago P, van Vliet H (2006) Building Up and Reasoning About Architectural Knowledge. In: Quality of Software Architectures, Springer Berlin Heidelberg.
- Additional literature will be announced in the course.

5 Thesis

<table>
<tr><td colspan="4">Abschlussarbeit</td></tr>
<tr><td colspan="4">Final Degree Module</td></tr>
<tr><td>Module number:
A.048.17002</td><td>Workload (h):
900</td><td>Credits:
30</td><td>Regular Cycle:
summer- / winter term</td></tr>
<tr><td>Language:
de / en</td><td>Semester number:
4. Semester</td><td>Duration (in sem.):
1</td><td>Module status (P=C/WP=CE)
P</td></tr>
</table>

1 **Module structure:**

	Course	**form of teachin**	**contact-time (h)**	**self-study (h)**	**status (C/CE)**	**group size (TN)**
a)	Working Plan (CEMA)		15	135	C	
b)	Master Thesis (CE)		30	720	C	

2 **Options within the module:**

None

3 **Admission requirements:**

The final thesis module can only be started when modules amounting to 45 credit points have been successfully completed. In the case of enrollment with conditions, the passing of the associated examinations must also be proven.

Prerequisites of course Arbeitsplan (CEMA):
Recommended: Depending on the chosen topic, knowledge from the chosen specialization module.

Prerequisites of course Masterarbeit (CE):
Recommended: Depending on the topic chosen, knowledge of the chosen area of specialization.

4 **Contents:**

Work plan:
After the topic has been agreed upon with the supervisor, an initial rough draft is made. On this basis and a first literature research, the student has to submit a work plan documenting the results to be achieved including milestones for the work.

Master thesis:
In the master thesis a problem is worked on according to scientific methods within a certain period of time. The thesis is thematically embedded in the scientific environment of the faculty and can make use of the multifaceted close cooperation with companies and industry. In addition to practical relevance, a master's thesis ensures in particular the suitability for methodical scientific work.

5 **Learning outcomes and competences:**

Within the framework of their final thesis, students work on a problem according to scientific methods within a certain period of time. The subject-specific methodological and interdisciplinary competences acquired in the course of the studies are to be applied accordingly. This includes in particular the structuring and planning of the individual work steps as well as the presentation of the results after completion of the work.

Non-cognitive competencies

- Commitment and engagement
- Learning competence
- Motivation to learn
- Motivational and volitional skills
- Writing and reading skills (academic)
- Self-direction skills

6 **Assessments:**

☒Final module exam (MAP) ☐Module exam (MP) ☐Partial module exams (MTP)

zu	Type of examination	Duration or scope	Weighting for the module grade
a) - b)	Masters Thesis incl. final presentation	max. 120 DIN A4-Pages incl. 45-60 min	100%

7 **Study Achievement:**

zu	Type of achievement	Duration or Scope	SL / QT
a)	Working Plan	150h	QP
b)			

8 **Prerequisites for participation in examinations:**

None

9	**Prerequisites for assigning credits:** Credits are awarded when the work plan has been verified and the master's thesis has been passed.
10	**Weighing for overall grade:** The module is weighted according to the twice the number of its credits (factor 2).
11	**Reuse in degree courses or degree course versions :** Masterstudiengang Computer Engineering v4 (CEMA v4)
12	**Module coordinator:** Dr.-Ing. Carsten Balewski
13	**Other Notes:** **Learning Materials, References** • Work plan: Depending on the chosen topic in consultation with the supervisor. • Master thesis: Depending on the chosen topic in consultation with the supervisor. **Methodological implementation** • Work plan: Direct consultation with supervisor. • Master thesis: Independent work supported by individual supervision.

6 Overview of the modules offered in the winter semester

7 Overview of the modules offered in the summer semester

- A.048.17002 Abschlussarbeit 456
- M.048.22003 Bauelemente der Leistungselektronik 181
- M.048.22013 Solar Electric Energy Systems 211
- M.048.22017 Leistungselektronik für die Energiewende 200
- M.048.22018 Energiesystemtechnik 190
- M.048.23012 Statistical and Machine Learning 232
- M.048.23019 Technische kognitive Systeme - Ausgewählte Kapitel 235
- M.048.24001 Digitale Sprachsignalverarbeitung 245
- M.048.24006 Elektromagnetische Feldsimulation 248
- M.048.24013 Feldberechnung mit der Randelementmethode 252
- M.048.24018 Numerische Simulation mit der Discontinuous Galerkin Time Domain Methode 258
- M.048.24019 Optical Waveguide Theory 261
- M.048.24023 Ausgewählte Kapitel der theoretischen Elektrotechnik 242
- M.048.25008 Analoge CMOS-Schaltkreise 280
- M.048.25017 Integrierte Schaltungen für die drahtlose Kommunikation 286
- M.048.26007 Fundamentals of Optics 298
- M.048.26010 Advanced Quantum Optics 300
- M.048.26011 Optoelectronics 317
- M.048.27013 Geregelte Drehstromantriebe 328
- M.048.27015 Ultraschallmesstechnik 337
- M.048.27028 Gekoppelte Felder 325
- M.048.27030 Topics in Advanced Control 334
- M.048.27031 Optimization-Based Control Methods 84
- M.048.27032 Nonlinear control of autonomous and robotic systems 82
- M.048.42941 Wissenschaftliches Arbeiten 20
- M.048.92007 Algorithms and Tools for Test and Diagnosis of Systems on a Chip 277
- M.048.92008 Digital Image Processing I 220
- M.048.92010 Digital Image Processing II 223
- M.048.92012 Robotics 229
- M.048.92019 Optical Communication A 305
- M.048.92020 Optical Communication B 308
- M.048.92022 Optical Communication D 314
- M.048.92035 Wireless Communications 270
- M.048.92037 Advanced Control 320
- M.048.92043 Advanced VLSI Design 274
- M.048.92045 Reinforcement Learning 226
- M.079.01290 Projektgruppe 17
- M.079.4002 Advanced Algorithms 367

8 Overview of module offerings in English

- A.048.17002 Final Degree Module 456
- M.048.210XX Statistical Signals 10
- M.048.22002 Intelligent Control of Electricity Grids 195
- M.048.22003 Power Electronic Devices 181
- M.048.22006 Power Electronics 197
- M.048.22013 Solar Electric Energy Systems 211
- M.048.22014 Energy Transition 192
- M.048.22020 Design of Energy Transition Scenarios 188
- M.048.23012 Statistical and Machine Learning 232
- M.048.23019 Cognitive Systems Engineering - Special Topics 235
- M.048.24001 Digital Speech Signal Processing 245
- M.048.24007 High Frequency Engineering 255
- M.048.24010 Optimal and Adaptive Filters 264
- M.048.24018 Numerical Simulations with the Discontinuous Galerkin Time Domain Method 258
- M.048.24019 Optical Waveguide Theory 261
- M.048.25008 Analog CMOS ICs 280
- M.048.25015 Radio Frequency Power Amplifiers 283
- M.048.25017 Integrated Circuits for Wireless Communications 286
- M.048.25019 Fast Integrated Circuits for Wireline Communications 289
- M.048.26001 High-Frequency Electronics 302
- M.048.26007 Fundamentals of Optics 298
- M.048.26010 Advanced Quantum Optics 300
- M.048.26011 Optoelectronics 317
- M.048.27013 Controlled AC Drives 328
- M.048.27030 Topics in Advanced Control 334
- M.048.27031 Optimization-Based Control Methods 84
- M.048.27032 Nonlinear control of autonomous and robotic systems 82
- M.048.90107 Analysis and Design of Electronic Circuits 14
- M.048.92001 Advanced System Theory 323
- M.048.92002 High Frequency Engineering 128
- M.048.92006 Advanced Topics in Robotics 217
- M.048.92007 Algorithms and Tools for Test and Diagnosis of Systems on a Chip 277
- M.048.92008 Digital Image Processing I 220
- M.048.92010 Digital Image Processing II 223
- M.048.92012 Robotics 229
- M.048.92014 Topics in Signal Processing 268
- M.048.92019 Optical Communication A 305
- M.048.92020 Optical Communication B 308
- M.048.92021 Optical Communication C 311
- M.048.92022 Optical Communication D 314

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